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Forest tree diseases of the prairie provinces

Y. Hiratsuka

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Cover photos:

Clockwise from upper left: western gall rust (*Endocronartium harknessii*); dwarf mistletoe (*Arceuthobium americanum*); Armillaria root rot (*Armillaria obscura*); and false tinder conk of aspen (*Phellinus tremulae*).

FOREST TREE DISEASES OF THE PRAIRIE PROVINCES

Y. Hiratsuka

INFORMATION REPORT NOR-X-286

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ABSTRACT

The major forest tree diseases of the Canadian prairie provinces are described in terms of their cause, distribution and hosts, symptoms and signs, disease cycle, damage, and control. The 25 coniferous, 15 deciduous, and 6 noninfectious disorders are illustrated by 47 pages of color photographs. An appendix listing the diseases by host, a glossary of technical terms, and a general index listing the common and scientific names of the hosts and the scientific names of the pathogens are also included.

RESUME

Les principales maladies des arbres forestiers des provinces des Prairies du Canada font l'objet d'une description précisant leur cause, leur répartition et leurs hôtes, leurs symptômes ou leurs signes, leur cycle, les ravages qu'elles causent et les mesures de lutte. Quarante-sept pages de photographies en couleurs illustrent les 25 maladies infectieuses dont sont victimes les conifères et les 15 maladies qui touchent les feuillus ainsi que 6 troubles non infectieux. Un appendice des maladies par hôtes, un glossaire des termes techniques et un index général des noms communs et scientifiques des hôtes et des noms scientifiques des pathogènes viennent compléter l'ouvrage.

ACKNOWLEDGMENTS

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—*Y. Hiratsuka*

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NOTE

The exclusion of certain manufactured products does not necessarily imply disapproval nor does the mention of other products necessarily imply endorsement by the Canadian Forestry Service.

INTRODUCTION

This publication describes and illustrates the major forest tree diseases of the prairie provinces of Canada (Alberta, Saskatchewan, and Manitoba) and is based mainly on information obtained by Forest Insect and Disease Survey Unit staff and forest pathologists of the Canadian Forestry Service in this region since the early 1950s. The Northern Forestry Centre in Edmonton was formed in 1970, amalgamating staff from laboratories in Winnipeg, Manitoba, and Calgary, Alberta, with staff from a smaller Edmonton laboratory.

Many biotic and abiotic agents affect the health of trees to various degrees. Traditionally, tree diseases include not only conditions caused by fungi, bacteria, viruses, and parasitic flowering plants but also disorders caused by climatic conditions, chemicals, and animals. Other major damage-causing agents such as insects and mites are usually considered separately. The above definition of tree diseases has been followed in this publication.

The 46 diseases or disease groups described in this publication were selected according to the following criteria:

1. economically important or potentially important,
2. visually conspicuous and recognized frequently, or
3. well known to the public because of media exposure.

Less emphasis was given to diseases restricted to ornamental or horticultural trees.

This publication was prepared mainly for forest managers, forest protection personnel of provincial forest agencies, students of post-secondary institutions (as a supplementary textbook for forest pathology or forest protection courses), park naturalists, provincial or municipal pest extension personnel, high school biology teachers, and the informed general public. Considering the intended audiences, the text of this publication is written in a simple form yet is scientifically accurate and informative.

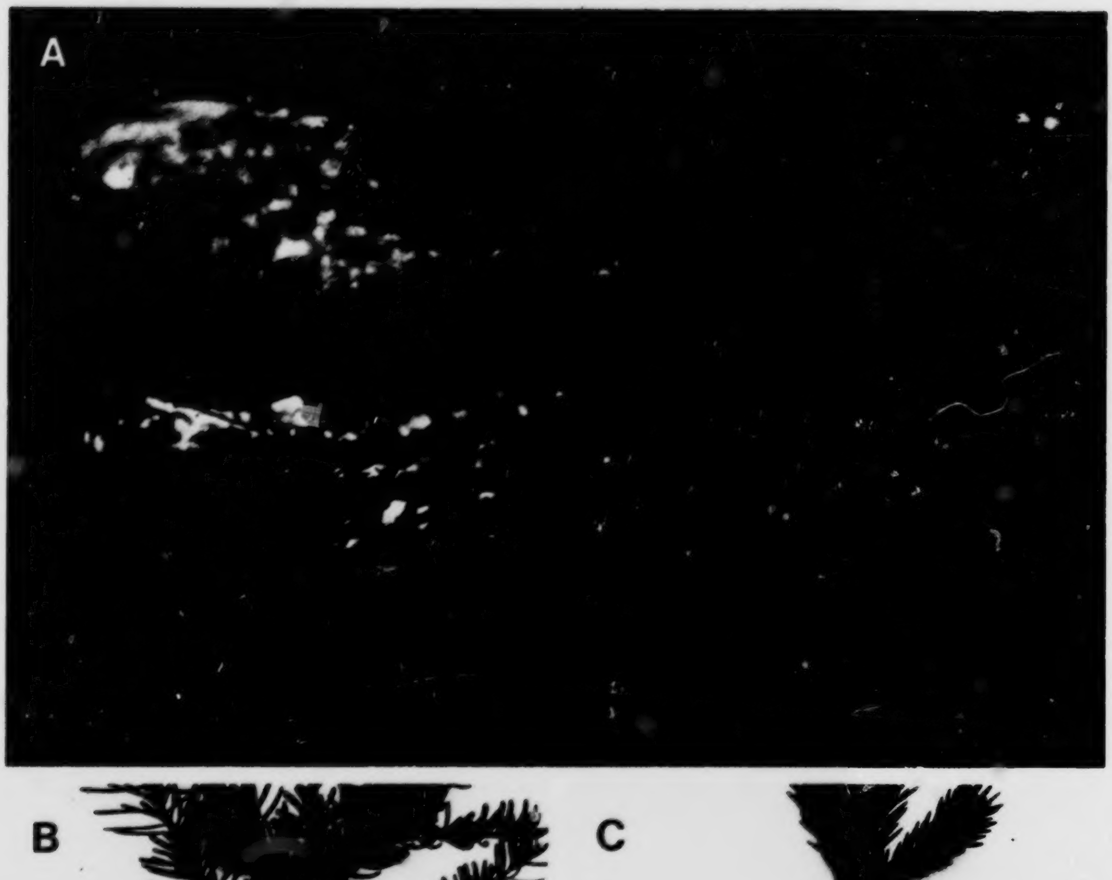
Each chapter contains basic information on the disease or group of diseases: cause, distribution and hosts, symptoms and signs, disease cycle, damage, and control. Selected references are listed in each chapter so that the reader can obtain further information. Copies of many of the listed publications are available from the Northern Forestry Centre. Comments in the control section are restricted to possible or feasible forms of control rather than prescriptions for specific control measures. An appendix arranged according to the generic names of the hosts lists all the diseases discussed in the publication. All technical and semitechnical terms used in the text and tables are defined in a glossary. An index follows that lists in alphabetical order the common and scientific names of the hosts and the scientific names of the pathogens, including cited synonyms (alternate or commonly used but not proper names).

The following two publications were used as standard sources for scientific and common names of the hosts, with a few exceptions:

Moss, E.H. 1983. Flora of Alberta. 2nd ed. revised by J.G. Packer. University of Toronto Press, Toronto, Ont.

Hosie, R.C. 1979. Native trees of Canada. 8th ed. Fitzhenry and Whiteside Ltd., Don Mills, Ont.

The synonyms of the Latin names of the pathogens are given only when older and more familiar names have been replaced by new ones.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SNOW MOLD OF CONIFERS

Cause

Two organisms are known to cause snow mold or brown felt blight of conifers. They are *Herpotrichia juniperi* (Duby) Petr. (= *H. nigra* Hartig) and *H. coulteri* (Pk.) Bose (≡ *Neopeckia coulteri* (Pk.) Sacc.). Both fungi belong to the class Ascomycetes.

Distribution and Hosts

In the prairie region, both species of fungus occur most frequently at high elevations in the Rocky Mountains, although they are also known to exist in other parts of the region. Hosts of *H. juniperi* are alpine fir (*Abies lasiocarpa* (Hook.) Nutt.), white spruce (*Picea glauca* (Moench) Voss), Engelmann spruce (*P. engelmannii* Parry), and species of juniper (*Juniperus* spp.). *Herpotrichia juniperi* is also reported from Siberia and northern Europe. *Herpotrichia coulteri* occurs only on species of pine. The main hosts in the prairie provinces are lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and limber pine (*P. flexilis* James). This disease has also been reported from a few locations in Europe.

Symptoms and Signs

Affected needles became discolored and die. The brown to black, felt-like mats of mycelium covering the lower branches of conifers are conspicuous and easily recognized (Figs. 1A–C).

Disease Cycle

Snow mold diseases develop during the winter on lower branches of the host trees that are covered by snow for a long time. Growth of fungi is apparently favored by the high humidity and relatively low temperature beneath the snow. The pathogens are probably disseminated by airborne ascospores or by mycelial growth from adjacent infected needles.

Damage

Although the appearance of the diseases is striking, damage is of minor consequence. Affected branches lose needles and often die, usually with no significant effect on the health of the tree. When seedlings or small trees are severely infected, however, considerable damage or even death may result.

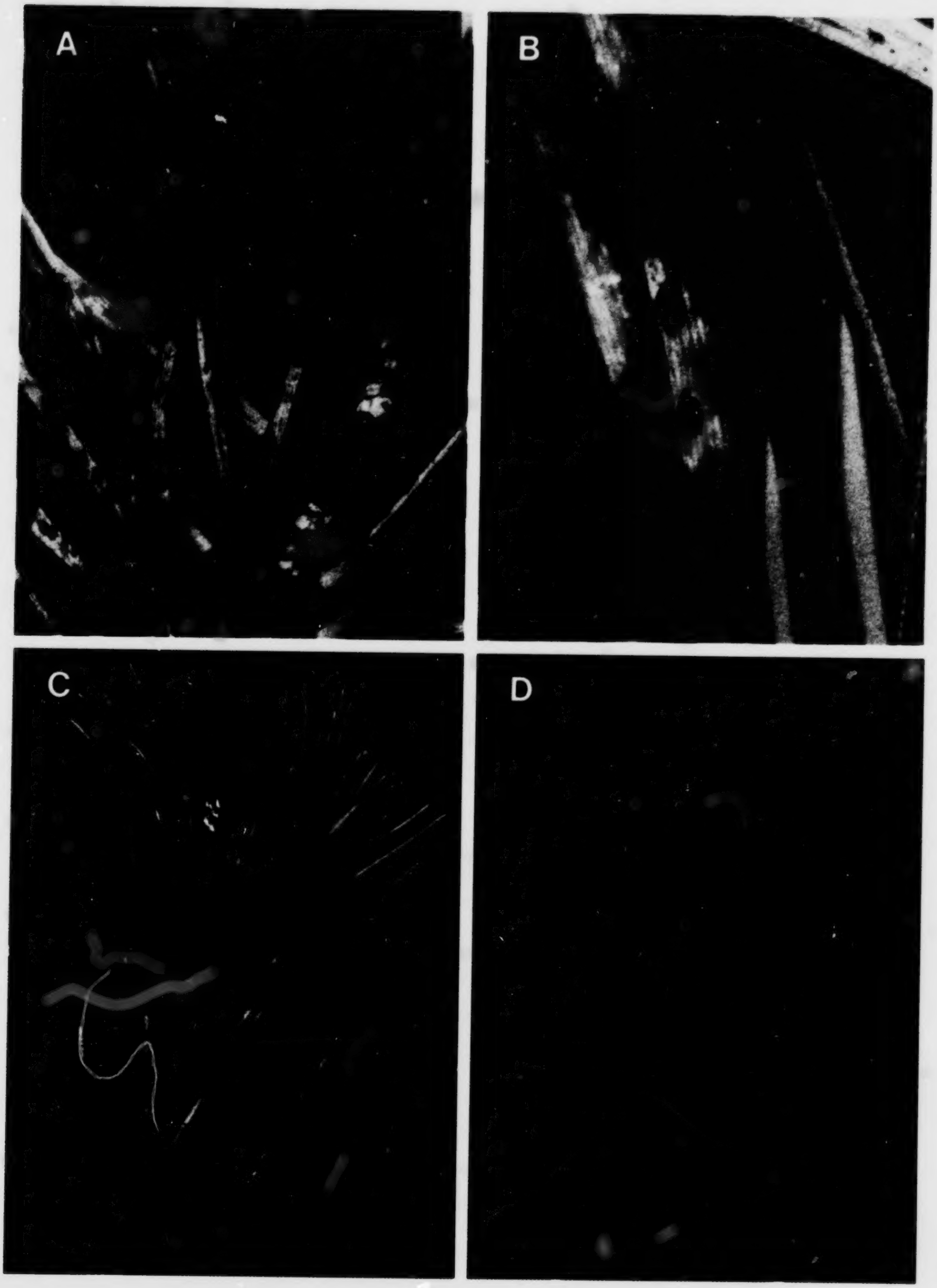
Control

Several fungicides have been tried in Europe to control *Herpotrichia juniperi*, but no such attempt has been made to control this group of diseases in Canada.

Selected Reference

Sivanesan, A. 1971. The genus *Herpotrichia* Fuckel. Commonw. Mycol. Inst., Richmond, England. Mycol. Pap. 127.

Figure 1. A snow mold of conifer caused by *Herpotrichia juniperi*. A. Lower branch infections on alpine fir, *Abies lasiocarpa*. **B.** An infected branch of alpine fir. **C.** An infected branch of Engelmann spruce, *Picea engelmannii*.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NEEDLE CASTS AND OTHER NEEDLE DISEASES OF PINE

Cause

Many needle casts and other needle diseases attack pine (*Pinus* spp.) and cause either premature casting or death of needles. Although casting is not always the typical symptom, needle cast is the term traditionally used for a group of needle diseases caused by fungi belonging to the family Hypodermataceae of the class Ascomycetes. Ten common needle casts and other needle diseases of pine are listed in Table 1 (p. 8). All except *Leptomelanconium cinereum* (Dearn.) Morgan-Jones, *Naemacyclus niveus* (Pers.:Fr.) Sacc., and *Thyriopsis halepensis* (Cke.) Th. & Syd. are needle cast fungi. Two other fungi, *Phaeoseptoria contortae* Parmelee & Y. Hiratsuka, and *Hendersonia pinicola* Wehm., are often found on pine needles, but they are probably secondary fungi, parasitizing the needle cast fungi *Davisomycella ampla* (Davis) Darker (Figs. A, B) and *Lophodermella concolor* (Dearn.) Darker (Figs. C, D), respectively. A needle rust and the Elytroderma needle cast are discussed separately (see Needle Rust of Hard Pines and Elytroderma Needle Cast of Pine).

Distribution and Hosts

Distribution and abundance of these diseases vary from year to year. Among the fungi listed in Table 1, *Lophodermium pinastri* (Shrad. ex Hook.) Chev. and *Naemacyclus niveus* are known on both hard and soft pines, *Bifusella linearis* (Pk.) Hoehn. and *Lophodermium nitens* Darker are known only on soft pines, and all other species are known only on hard pines.

Symptoms and Signs

Various patterns of discoloration, death, and casting of needles are the most common symptoms of this group of diseases. The main distinguishing features of each species are listed in Table 1. Positive identification of needle casts and other needle diseases can be accomplished only when mature asci and ascospores are present and can be examined microscopically, although a few species exhibit specific symptoms and can be identified easily.

Disease Cycle

Ascospores produced on second- or third-year needles infect current-year needles in the spring or early summer. Symptoms may not show until late summer or fall. Mature fruiting bodies are usually produced during the winter and sporulate in the spring.

Damage

None of the diseases discovered in this chapter kill large trees or affect their health significantly unless heavy and repeated infections occur in successive years. Extensive defoliation can affect growth and shape of trees. *Lophodermium pinastri* is known to cause significant damage in nurseries elsewhere, but it has not been recognized as an important disease in nurseries in the prairie provinces. *Naemacyclus minor* Butin, which is closely related to *N. niveus*, has been reported to cause significant damage on planted Scots pine (*Pinus sylvestris* L.) in the eastern United States and has been recognized in a few Scots pine tree nurseries in Manitoba in recent years.

Control

No control measure is necessary for these diseases in this region at this time, although protective fungicide sprays are considered effective to prevent spread of *Lophodermium pinastri* in nurseries in the United States.

Selected References

Darker, G.D. 1932. The Hypodermataceae of conifers. Contrib. Arnold Arbor. 1:1-131.

Darker, G.D. 1967. A new *Davisomycella* species on *Pinus banksiana*. Can. J. Bot. 45:1445-1449.

Darker, G.D. 1967. A revision of the genera of the Hypodermataceae. Can. J. Bot. 45:1399-1444.

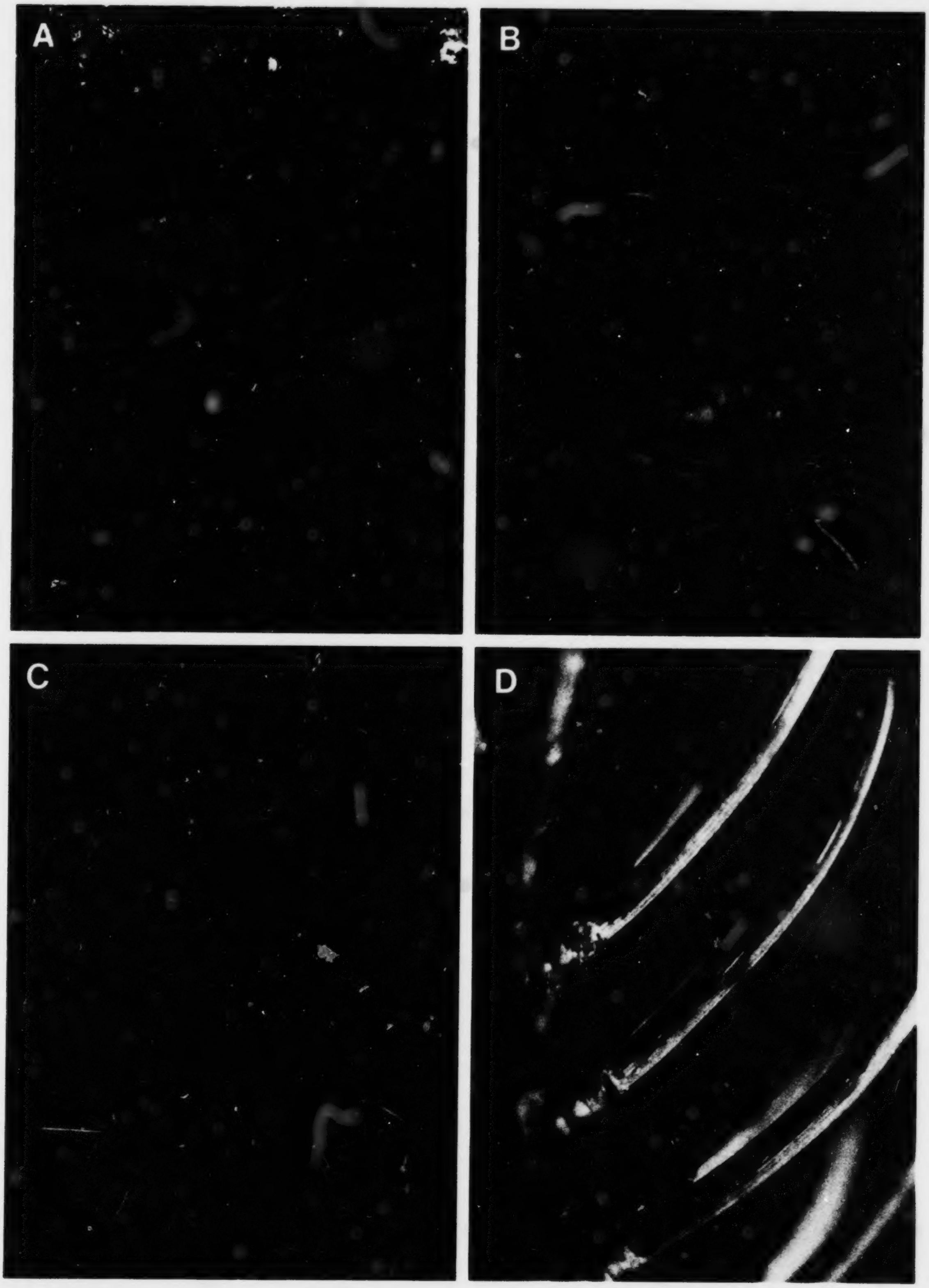
Hunt, R.S.; Ziller, W.G. 1978. Host-genus keys to Hypodermataceae of conifer leaves. Mycotaxon 7:481-496.

Nicholls, T.H.; Skilling, D.D. 1974. Control of lophodermium needle cast disease in nurseries and Christmas tree plantations. U.S. Dep. Agric., For. Serv., North. Cent. For. Exp. Stn., St. Paul, Minn. Res. Pap. NC-110.

Figure 2. Needle casts of pine (*Pinus* spp.). A, B. *Davisomycella ampla* on lodgepole pine, *Pinus contorta* var. *latifolia*. C, D. *Lophodermella concolor* on lodgepole pine.

Table 1. Symptoms and signs of needle casts and other needle diseases of pine in the prairie provinces

Organism	Symptoms and signs
Bifusella linearis (Pk.) Hoehn. **Needle cast**	Hysterothecia elongated, shiny black, subcuticular, of variable length on discolored (sordid) needles; ascospores elongated dumb-bell-shaped (bifusiform), 41–60 × 5–7 μm
Davisomycella ampla (Davis) Darker ≡ *Hypodermella ampla* (Davis) Dearn. **Needle cast**	Hysterothecia ellipsoid, dark brown on sordid section of needles, bordered with orange-brown bands; ascospores clavate, tapering toward the base, 60–130 × 5–8 μm, gelatinous sheath 3–7 μm thick (Figs. 2A, B)
Elytroderma deformans (Weir) Darker **Elytroderma needle cast** (See Elytroderma Needle Cast of Pine)	Hysterothecia elongate, black, on brown second-year needles, sporulate on straw-colored third-year needles, systemic infection; ascospores cylindrical, 90–118 × 6–8 μm, two-celled, gelatinous sheath 6–10 μm thick (Figs. 3A–D)
Leptomelanconium cinereum (Dearn.) Morgan-Jones ≡ *Gloeocoryneum cinereum* (Dearn.) Windl. **Needle fungus**	Black, irregular to circular cushion of spores (acervuli) under hypodermis, become erumpent, on discolored needles; conidia brown, ovoid or ellipsoid, thick-walled, verrucose, three- to six-celled, 20–25 × 6–12 μm
Lophodermella concolor (Dearn.) Darker ≡ *Hypodermella concolor* (Dearn.) Darker **Needle cast**	Hysterothecia inconspicuous, on straw-colored needles under depressions; ascospores clavate, tapering toward the base, 40–60 × 6–8 μm, gelatinous sheath 2–3 μm thick (Figs. 2C, D)
Lophodermella montivaga Petr. ≡ *Hypodermella montivaga* (Petr.) Dearn. **Needle cast**	Hysterothecia elongate, dark brown, with prominent central slits; ascospores clavate, hyaline, 40–50 × 3–4 μm, gelatinous sheath 3–4 μm thick
Lophodermium nitens Darker **Needle cast**	Hysterothecia subcuticular, shiny black, elliptical, on discolored needles; ascospores filiform, 80–120 × 2–3 μm, gelatinous sheath 2 μm thick
Lophodermium pinastri (Shrad. ex Hook.) Chev. **Needle cast**	Hysterothecia subepidermal, dull black, elliptical, on discolored needles; ascospores filiform, 85–140 × 1.5–2.0 μm, gelatinous sheath 2 μm thick
Naemacyclus niveus (Pers.:Fr.) Sacc. **Naemacyclus needle cast**	Ascocarps concolorous with discolored needles, elliptical, sub-hypodermal, open by a split; ascospores filiform, with two septa, 75–120 × 2.5–3.5 μm; conidia in hyaline pycnidia, 12–16 × 1 μm
Thyriopsis halepensis (Cke.) Th. & Syd. **Needle spot**	Ascocarps with chlorotic spots on living needles, black, amphigenous, subcuticular, roundish; ascospores ellipsoid, two-celled, hyaline to brown, 11–16 × 4–8 μm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ELYTRODERMA NEEDLE CAST OF PINE

Cause

Elytroderma needle cast of pine (*Pinus* spp.) is caused by the fungus *Elytroderma deformans* (Weir) Darker, a needle cast fungus belonging to the family Hypodermataceae of the class Ascomycetes.

Distribution and Hosts

This disease is found throughout western North America and in several locations in eastern North America (Ontario and Georgia). Main hosts of this disease are ponderosa pine (*Pinus ponderosa* Laws.) and lodgepole pine (*P. contorta* Dougl. var. *latifolia* Engelm.), but it has also been reported on jack pine (*P. banksiana* Lamb.), shortleaf pine (*P. echinata* Mill.), pinyon pine (*P. edulis* Engelm.), and Jeffrey pine (*P. jeffreyi* Grev. & Balf.).

Symptoms and Signs

The pathogen is perennial in the twigs and invades most or all of the new needles soon after they appear. Conspicuous reddish brown discoloration of needles begins in the spring or early summer of their second year (Figs. 3A-C). Third-year needles are straw colored and have characteristic slender black fruiting bodies (hysterothecia) (Fig. 3D). Compared with the distinctive witches' broom symptom on ponderosa pine, symptoms on lodgepole and jack pines are less conspicuous but cause distinctive thinning and distortion of the crown.

Disease Cycle

Once the fungus infects a tree it lives systemically in the tissue until the tree dies. Spread of the disease to different branches in the same tree seems to occur often through the stem. In the spring, ascospores produced in the fruiting bodies mature and may infect new shoots, but large numbers of new infections seem to occur only once in several years.

Damage

Damage caused by this disease on lodgepole or jack pines in the prairie provinces is probably greatly underestimated. Because of the systemic nature of the infection, the vigor of trees is reduced gradually over many years. Also, when the disease affects a large number of trees in a stand, the reduction in increment is likely to be significant.

Control

No control measures have been considered for this disease on lodgepole and jack pines in the prairie provinces; however, accelerated harvesting of heavily infested stands, thinning, and eliminating trees with top infections have been recommended for ponderosa pine in the western United States.

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Childs, T.W. 1967. *Elytroderma* needle cast. Pages 45-47 *in* Important forest insects and diseases of mutual concern to Canada, the United States and Mexico. Can. Dep. For. Rural Dev., Ottawa, Ont. Publ. 1180.

Childs, T.W. 1968. Elytroderma disease of ponderosa pine in the Pacific Northwest. U.S. Dep. Agric., For. Serv., Pac. Northwest For. Range Exp. Stn., Portland, Oreg. Res. Pap. PNW-69.

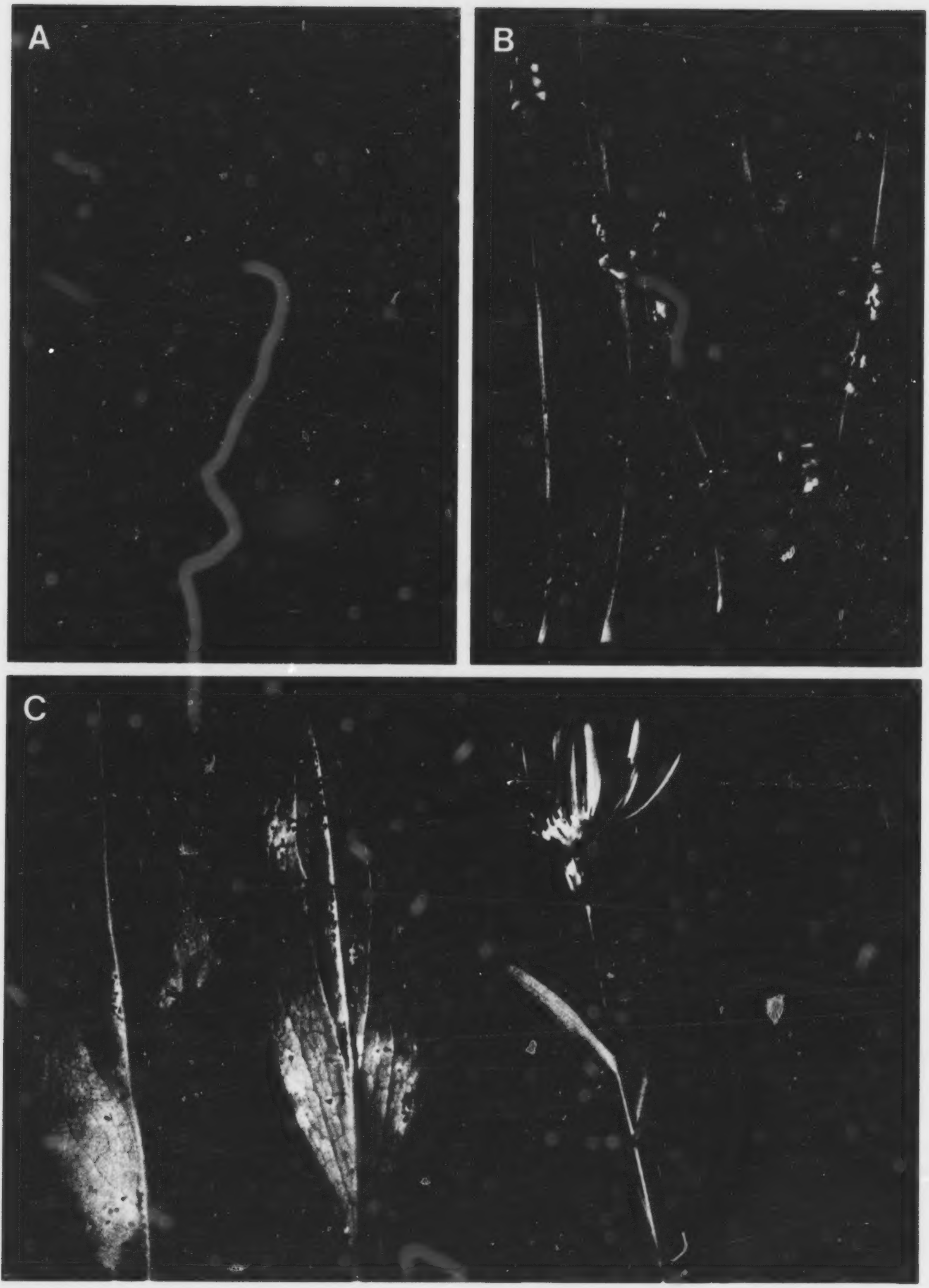
Hunt, R.S. 1978. Elytroderma disease of pines. Environ. Can., Can. For. Serv., Pac. For. Res. Cent., Victoria, B.C. For. Pest Leafl. FPL 27.

Hunt, R.S.; Ziller, W.G. 1978. Host-genus keys to the Hypodermataceae of conifer leaves. Mycotaxon 7:481-496.

Lightle, P.C. 1954. The pathology of *Elytroderma deformans* on ponderosa pine. Phytopathology 44:557-569.

Roth, L.E. 1959. Perennial infection of ponderosa pine by *Elytroderma deformans*. For. Sci. 5:182-191.

Figure 3. Elytroderma needle cast of pine (*Pinus* spp.) caused by *Elytroderma deformans*. A, B. Heavily infected lodgepole pine, *Pinus contorta* var. *latifolia*. **C.** Typical reddish brown discoloration of second-year needles and straw-colored third-year needles with black fruiting bodies. **D.** Straw-colored needles with black elongated fruiting bodies.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NEEDLE RUST OF HARD PINES

Cause

The rust fungus *Coleosporium asterum* (Diet.) Syd. (= *C. solidaginis* Thuem.) is the pathogen of the needle rust of hard pines (*Pinus* spp.). There are at least two different forms within the species.

Distribution and Hosts

An eastern North American species, *C. viburni* Arth., occurs in Manitoba on an alternate host, viburnum (*Viburnum lentago* L.), but it has not yet been found on pine. The western form of *C. asterum* is known in western North America, including all the prairie provinces and the Northwest Territories, but other forms are distributed in eastern North America and Asia. The main hosts of this rust in the prairie provinces are lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and jack pine (*P. banksiana* Lamb.), but the rust is also known to occur on Scots pine (*P. sylvestris* L.). Alternate hosts of the rust are several species of aster (*Aster* spp.) and goldenrod (*Solidago* spp.).

Symptoms and Signs

This disease can be recognized easily by the orange-yellow aeciospores produced in whitish cylindrical columns (peridermia) on second-year needles (Figs. 4A, B). Infected needles are often paler in color and drop prematurely. Pustules of powdery, yellow urediniospores are produced on the lower side of leaves of alternate hosts, and smooth, raised, orange-red telia appear later in the growing season (Fig. 4C).

Disease Cycle

Infections on pine are initiated on first-year needles in late summer by basidiospores produced on alternate hosts (asters and goldenrods). The rust overwinters in infected needles and produces spermogonia and aecia the next spring. Aeciospores are disseminated by wind and infect leaves of alternate hosts. Urediniospores are then produced that can reinfect alternate hosts. Later in the season, teliospores develop on the alternate hosts and germinate to produce basidiospores.

Damage

Generally, the disease does not cause significant damage, but repeated heavy infections year after year could significantly reduce the growth of small trees. In situations such as intensively managed tree farms or nurseries, this rust has reduced the quality of trees and has been a limiting factor in the sale of ornamental or Christmas trees.

Control

No commercial attempt has been made to control this disease, but eradication of alternate hosts in and around young pine plantations and protective spray of fungicides have been tried successfully on several occasions.

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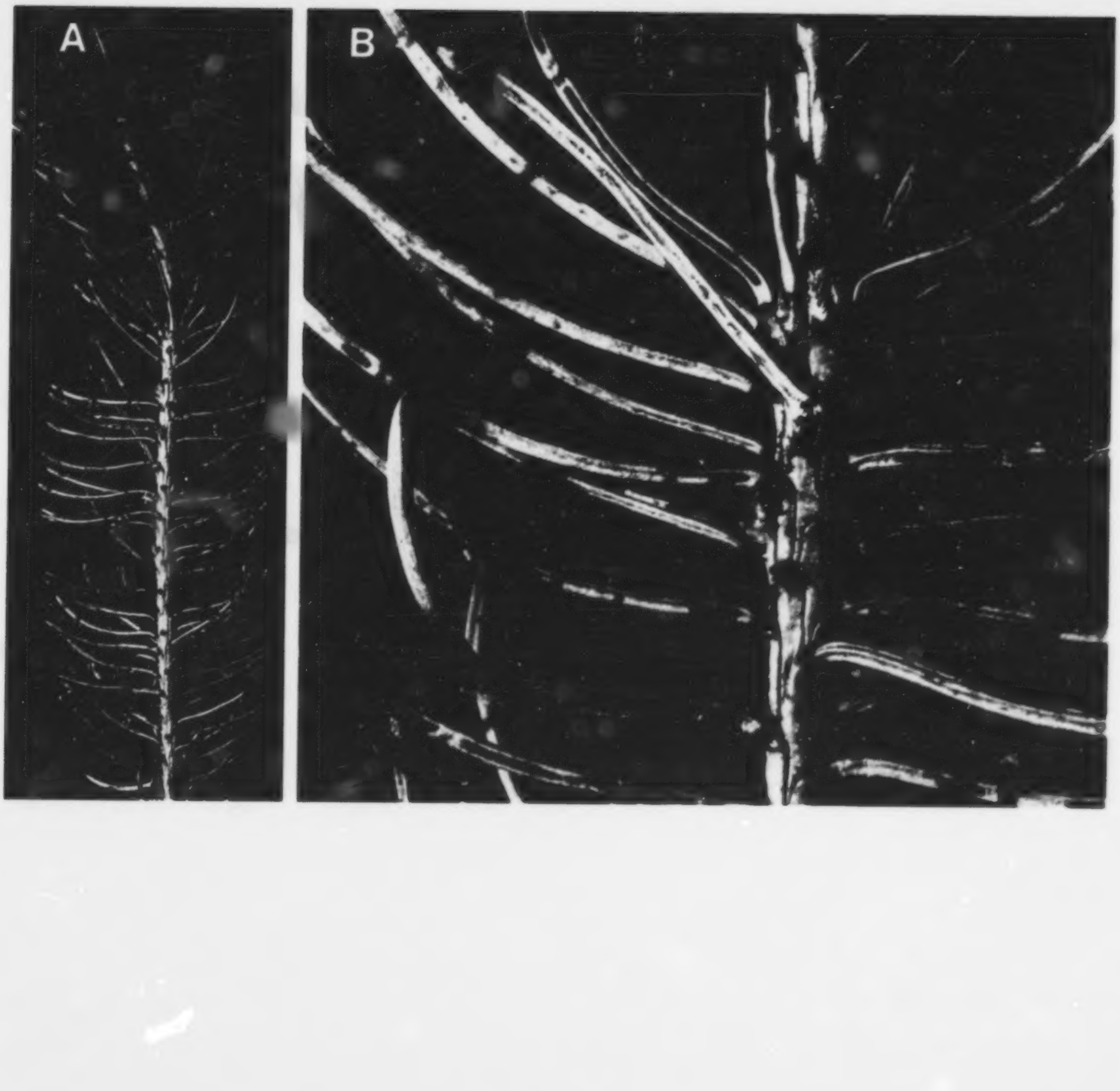
Figure 4. Needle rust of hard pines (*Pinus* spp.) caused by *Coleosporium asterum*. A. A heavily infected branch of lodgepole pine, *Pinus contorta* var. *latifolia*. **B.** Close-up of infected needles with cup-shaped aecia. **C.** Uredinia and telia on an alternate host, Lindley's aster (*Aster ciliolatus*).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NEEDLE CASTS AND OTHER NEEDLE DISEASES OF SPRUCE

Cause

There are three needle casts of spruce (*Picea* spp.) in the prairie provinces: *Isthmiella crepidiformis* (Darker) Darker (≡ *Bifusella crepidiformis* Darker), *Lirula macrospora* (Hartig) Darker (≡ *Lophodermium macrospora* (Hartig) Rehm.), and *Lophodermium piceae* (Fckl.) Hoehn. Needle casts is the term used for a group of needle diseases caused by fungi belonging to the family Hypodermataceae of the order Ascomycetes. Another fungus, *Lophophacidium hyperboreum* Lager., which causes snow blight, is also common in the region. Spruce needle rusts and yellow witches' broom are discussed separately (see Needle Rusts of Spruce and Yellow Witches' Broom of Spruce).

Distribution and Hosts

Spruce needle casts and snow blight attack all native spruces and are distributed widely in the prairie provinces.

Symptoms and Signs

For all three needle casts, second-year needles are usually discolored brown or straw colored, and black fruiting bodies (hysterothecia) are produced on the discolored needles. The fruiting bodies are either elongated (*Lirula macrospora*) (Figs. 5A, B), fusiform (*I. crepidiformis*), or short elliptical (*Lophodermium piceae*). For positive identification, ascospores produced in the fruiting bodies have to be examined. Spore measurements for the three needle casts are as follows: *I. crepidiformis*, two-celled, 60–75 × 8.0–8.5 μm; *Lirula macrospora*, one-celled, 56–68 × 2.5–3.5 μm; and *Lophodermium piceae*, one-celled, 60–95 × 1.5–2.0 μm. Fruiting bodies of *Lophophacidium hyperboreum* usually appear as circular, immersed brown patches raised into elliptical, straw-colored blisters on the underside of brownish, discolored needles. Ascospores are one-celled, 15–23 × 6–8 μm.

Disease Cycle

Windborne ascospores produced on second-year needles infect newly formed needles in the spring. Symptoms may show up in the first year, but the spores usually develop only on second-year needles.

Damage

Infected needles drop prematurely, usually in their second year. Severe infections in successive years affect tree growth, but needle casts do not kill the infected trees. Needle casts can be economically important in ornamental and Christmas trees because heavy infection significantly affects the appearance of trees and thus reduces their market value.

Control

No control measure is available or necessary at this time in most situations, although a timely protective fungicide spray is recommended for high-value ornamental and Christmas trees.

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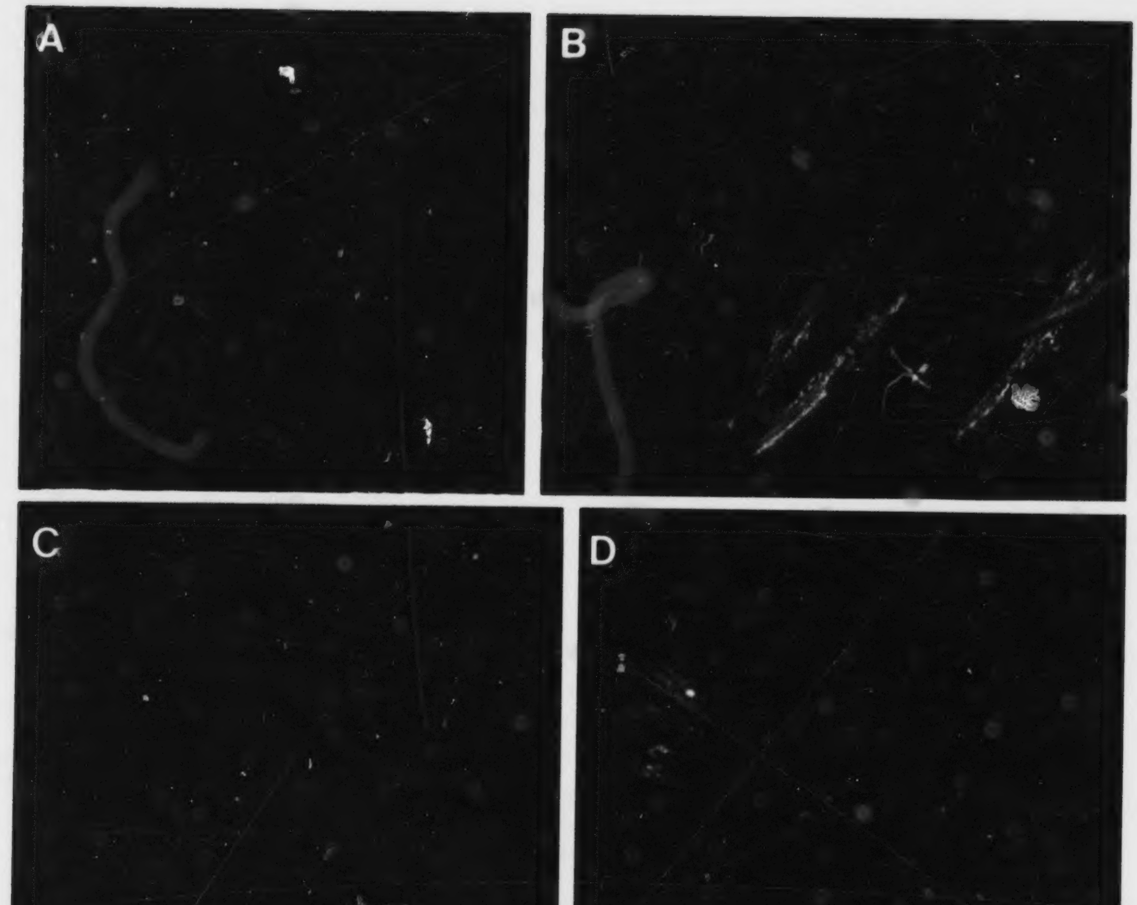
Funk, A. 1985. Foliar fungi of western trees. Can. For. Serv., Pac. For. Res. Cent., Victoria, B.C. Inf. Rep. BC-X-265.

Hunt, R.S.; Ziller, W.G. 1978. Host-genus keys to the Hypodermataceae of conifer leaves. Mycotaxon 7(3):481–496.

Figure 5. A needle cast of spruce (*Picea* spp.) caused by *Lirula macrospora*. A. Straw-colored, infected second-year needles of white spruce, *Picea glauca*. **B.** Close-up of infected, straw-colored needles with elongated black fruiting bodies.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NEEDLE RUSTS OF SPRUCE

Cause

Eight needle rusts are known on various species of spruce (*Picea* spp.) in the prairie provinces (Table 2, p. 18). Among them, *Chrysomyxa ledicola* Lagh. and *C. ledi* d By. are probably the most prevalent and most important species in the region, followed by the *Pucciniastrum* species. Several subspecies within *C. ledi* have been recognized by a few authors based on minor morphological differences and alternate host ranges. Yellow witches' broom caused by *C. arctostaphyli* Diet. is discussed separately (see Yellow Witches' Broom of Spruce).

Distribution and Hosts

All species except *C. weirii* Jacks. are heteroecious, that is, they need alternate hosts besides spruce to complete their life cycles. Alternate hosts for the rust species are listed in Table 2. *Chrysomyxa weirii* is autoecious (does not alternate hosts). The distribution of *C. weirii* and *Pucciniastrum sparsum* (Wint.) E. Fisch. is limited mostly to the Rocky Mountain region, whereas *C. woroninii* Tranz. occurs in northern parts of the prairie provinces. Other needle rusts are found across the prairie provinces where native white, black, and Engelmann spruces (*Picea glauca* (Moench) Voss, *P. mariana* (Mill.) B.S.P., and *P. engelmannii* Parry) and suitable alternate hosts occur.

Symptoms and Signs

One common symptom of infection by *C. ledicola*, *C. ledi*, *P. sparsum*, and *P. americanum* (Farl.) Arth. (and *P. arcticum* Tranz.) is a slight discoloration of needles. On the needles may be found small, dot-like sexual fruiting structures (spermogonia), which produce spermatia, and cup- or tongue-shaped structures (aecia), which produce powdery, orange-yellow aeciospores (Figs. 6A, B). Infected needles drop prematurely. Positions of the spermogonia on the needles (subcuticular or subepidermal) and size of aeciospores are important characteristics for species identification. *Chrysomyxa woroninii* attacks only young buds, causing them to produce small, abnormal, cone-shaped or swollen branch tips (Figs. 6C, D). On these buds the spermogonia and aecia are produced. The autoecious rust *C. weirii* produces tongue-shaped gelatinous telia consisting of teliospores on discolored parts of needles.

Disease Cycle

Powdery, orange spores (aeciospores) produced on spruce needles infect young leaves of the alternate host, *Ledum* spp. (Fig. 6E), in the spring. Small infected areas develop on the leaves of *Ledum* spp. in the fall. After the fungus overwinters, waxy mound-like spore structures (telia) are formed (Fig. 6F). Upon germination of teliospores, fragile basidiospores are formed and become windborne. They may infect young needles of spruce. Later, orange pustules (uredinia) are formed on the same leaves of *Ledum* spp., and powdery, orange spores (urediniospores) produced in them can reinfect leaves of *Ledum* spp. The life cycles of *Pucciniastrum* spp. are similar to those of *C. ledicola* and *C. ledi*, except that telia overwinter on dead plants on the ground rather than on live leaves. When *C. woroninii* infects *Ledum* spp., small witches' brooms are produced and the fungus can survive on them perennially.

Damage

Infection by needle rusts, especially *C. ledicola* and *C. ledi*, occasionally can be very heavy, and all or most of the current-year needles can be affected and dropped prematurely. Heavy infections seldom occur in successive years, however, and trees do not seem to be damaged significantly from heavy infection of rusts. Heavy infection of ornamental and Christmas trees will significantly reduce their value.

Control

Control measures have not been developed nor are they necessary for this group of rusts in the forests in our region. A timely protective spray of fungicides is known to be effective and is economically feasible in certain situations such as Christmas tree farms or tree nurseries that grow spruces for ornamentals.

Continued on next page.

Figure 6. Needle rusts of spruce (*Picea* spp.). A. Heavy infection of *Chrysomyxa ledicola* on white spruce, *Picea glauca*. **B.** Close-up of *C. ledicola* infected needles of white spruce showing ridges of aecia. **C.** A cluster of *C. woroninii* infected buds of white spruce. **D.** Close-up of deformed buds caused by *C. woroninii*. **E.** Common Labrador tea (*Ledum groenlandicum*), one of the main alternate hosts of *C. ledicola*, *C. ledi*, and *C. woroninii*. **F.** Uredinia and telia of *C. ledicola* on the upper surface of common Labrador tea.

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Ziller, W.G. 1974. The tree rusts of western Canada. Environ. Can., Can. For. Serv., Ottawa, Ont. Publ. 1329.

Table 2. Symptoms and signs of needle rusts of spruce in the prairie provinces

Organism	Telial hosts[1]	Symptoms and signs
Chrysomyxa arctostaphyli Diet. **Spruce broom rust** (See Yellow Witches' Broom of Spruce)	Kinnikinnick (*Arctostaphylos uva-ursi* (L.) Spreng.); III only, on underside of leaf (Fig. 8D)	Perennial, produces conspicuous witches' broom; spermogonia subepidermal; aeciospores 16–25 × 23–35 μm (Figs. 8A–C)
Chrysomyxa ledi d By. **Small-spored spruce—Labrador tea rust** (Several subspecies are recognized mainly by telial host)	Labrador tea (*Ledum* spp.); II, III on underside of leaf	Causes premature defoliation; spermogonia subepidermal; aeciospores 11–25 × 18–31 μm
Chrysomyxa ledicola Lagh. **Large-spored spruce—Labrador tea rust**	Labrador tea (*Ledum* spp.); II, III on upper side of leaf (Fig. 6C)	Causes premature defoliation; spermogonia subepidermal; aeciospores 22–34 × 27–46 μm (Figs. 6A, B)
Chrysomyxa weirii Jacks. **Weir's spruce cushion rust** (Autoecious species)	Spruce (*Picea* spp.); III on needles	Orange-yellow tongue-like telia on discolored bands on second-year needles
Chrysomyxa woroninii Tranz. **Spruce shoot rust** (Some reports indicate that this is an autoecious species)	Labrador tea (*Ledum* spp.) (causes witches' broom); II, III on systemically infected leaf	Attacks young buds and causes small cone-shaped swelling; spermogonia subepidermal; aeciospores 19–34 × 33–62 μm (Figs. 6D, F)
Pucciniastrum americanum (Farl.) Arth. and *P. arcticum* Tranz. **Spruce-raspberry rust**	Raspberry (*Rubus* spp.); II, III on underside of leaf	Causes premature defoliation; spermogonia subcuticular; aeciospores 13–16 × 16–26 μm
Pucciniastrum sparsum (Wint.) E. Fisch. **Spruce-bearberry rust**	Alpine bearberry (*Arctostaphylos rubra* (Rehder & Wils.) Fern.); II, III on underside of leaf	Causes premature defoliation; spermogonia subcuticular; aeciospores 13–22 × 20–32 μm with elongate smooth spots

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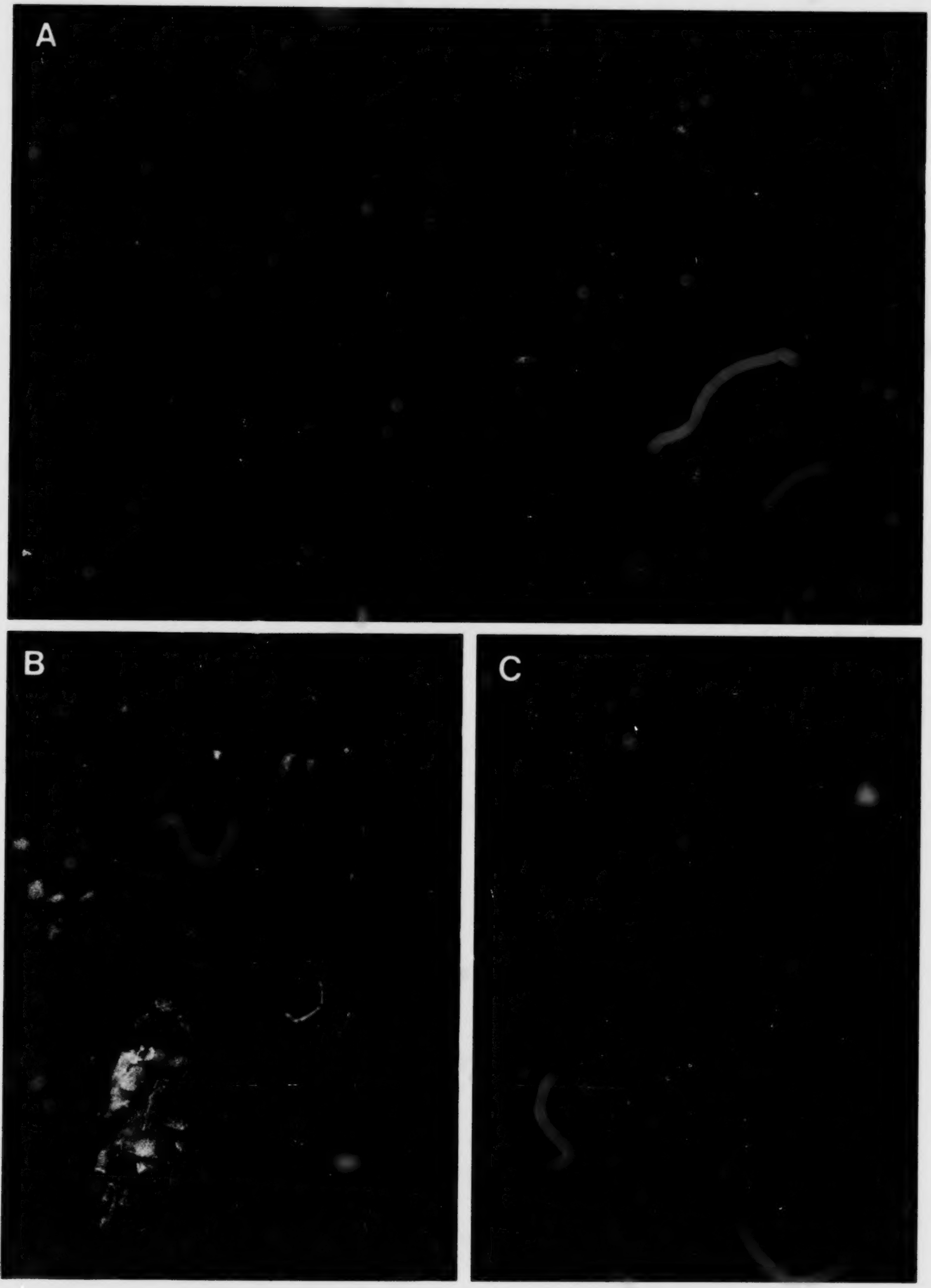
[1] II = uredinial state; III = telial state.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SPRUCE CONE RUST

Cause

Spruce cone rust is caused by the rust fungus *Chrysomyxa pirolata* Wint.

Distribution and Hosts

Spruce cone rust is distributed in patches across northern North America, Europe, and Asia. All native North American spruce are susceptible, but white spruce (*Picea glauca* (Moench) Voss), black spruce (*P. mariana* (Mill.) B.S.P.), and Engelmann spruce (*P. engelmannii* Parry) are natural hosts in the prairie provinces. Introduced blue spruce (*P. pungens* Engelm.) is also reported to be susceptible.

Alternate hosts of this fungus are several species of wintergreens (*Orthilia* spp., *Pyrola* spp., and *Moneses* spp.). The main alternate hosts in the prairie provinces are one-sided wintergreen (*Orthilia secunda* (L.) House ≡*Pyrola secunda* L.), common pink wintergreen (*Pyrola asarifolia* Michx.; Fig. 7A), and one-flowered wintergreen (*Moneses uniflora* (L.) A. Gray).

Another cone rust species, *C. monesis* Ziller, occurs in the Pacific coast region of North America.

Symptoms and Signs

This rust attacks only cones of spruce, never the needles. The rust infects cones systemically, causing them to open prematurely. They become brown and thus can be distinguished from the healthy, closed green ones (Fig. 7B). Orange-yellow aeciospores are produced on diseased cones (Fig. 7C). In certain years, spores from infected cones are produced in such quantity that the forest floor or lake surface appears orange because of the fallen spores.

Several other species of spruce needle rust such as *Chrysomyxa ledicola* Lagh., *C. ledi* d By., and *Pucciniastrum americanum* (Farl.) Arth. occasionally infect cones, but unlike *C. pirolata*, their infections are localized and not systemic. On alternate hosts, uredinia and telia are produced on the lower surface of the leaves. The infected leaves are often smaller and yellowish. Pustules of uredinia are powdery and orange. Telia develop as flat, waxy, yellowish red pustules (Fig. 7A).

Disease Cycle

Basidiospores produced on alternate hosts infect female flowers of spruce probably during or soon after pollination. Systemically infected cones produce aeciospores, which are responsible for infection on alternate hosts. On alternate hosts, uredinia and telia are produced on systemically infected leaves (Fig. 7A). Urediniospores spread the rust to other alternate hosts. Teliospores germinate to produce basidiospores.

Damage

Most of the infected cones do not produce viable seeds. Up to 50% of the cone crop can be infected, and in certain locations damage to 20–30% of the cone crop is common. In selected harvesting areas or seed orchards, high levels of infection during cone crop years are economically important; however, healthy seeds superficially contaminated with the rust spores from infected cones cannot be infected.

Control

No control measures have been developed for this disease, but control of alternate hosts in and around high-value seed orchards or seed-collecting areas may become important and economically feasible.

Selected References

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Sutherland, J.R.; Hopkinson, S.J.; Farris, S.H. 1984. Inland spruce cone rust, *Chrysomyxa pirolata*, in *Pyrola asarifolia* and cones of *Picea glauca*, and morphology of the spore stages. Can. J. Bot. 62:2441–2447.

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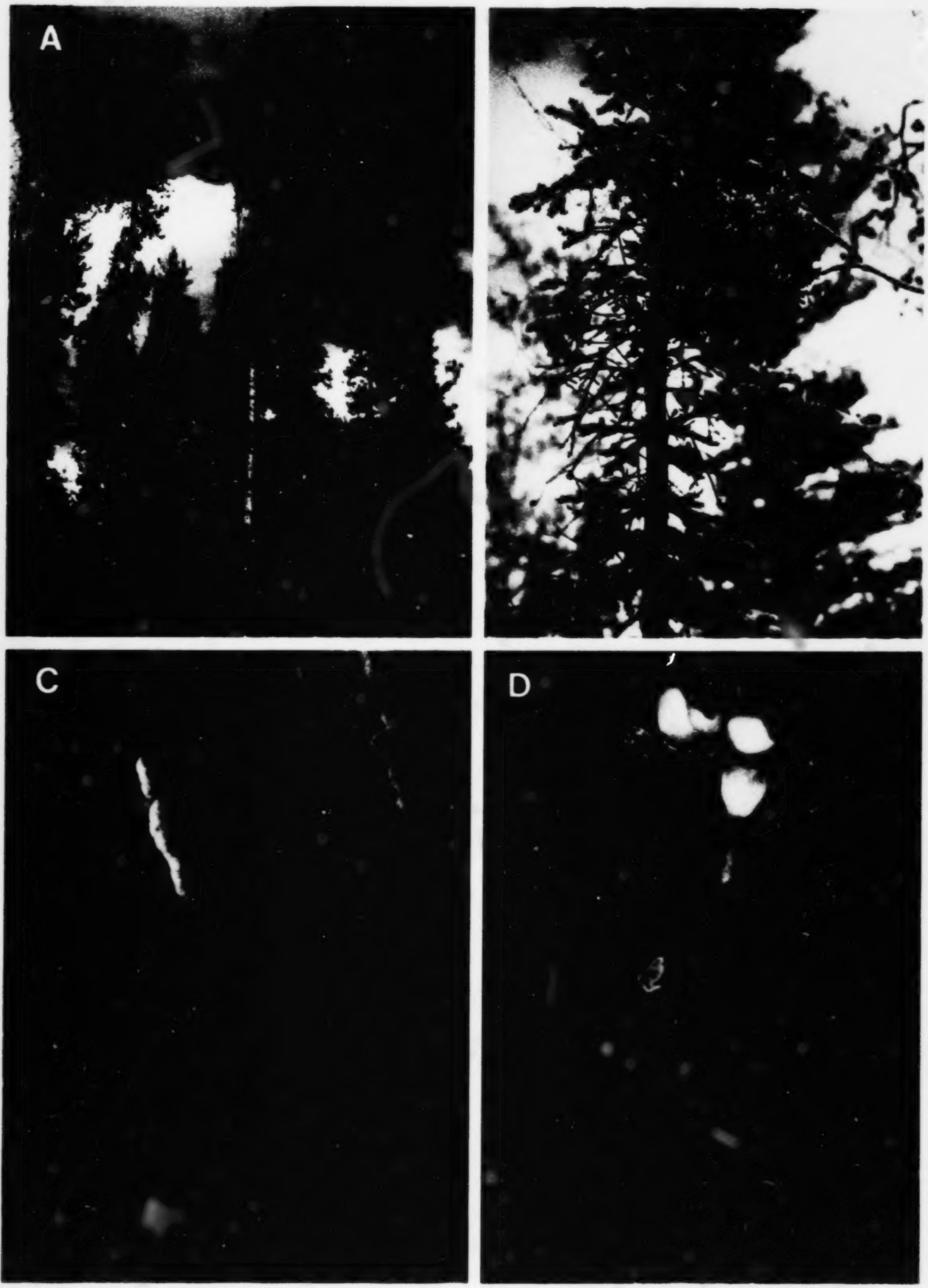
Figure 7. Spruce cone rust, *Chrysomyxa pirolata*. A. Systemically infected (left) and healthy (right) common pink wintergreen, *Pyrola asarifolia*. **B.** An infected cone (brown open cone) and two uninfected green cones of white spruce, *Picea glauca*. **C.** An infected cone of white spruce cut open to show yellow systemically produced aecia.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YELLOW WITCHES' BROOM OF SPRUCE

Cause

Yellow witches' broom of spruce (*Picea* spp.) is caused by the rust fungus *Chrysomyxa arctostaphyli* Diet. Before the life cycle was clarified in 1961, this rust was called by its imperfect name, *Peridermium coloradense* Arth. & Kern.

Distribution and Hosts

Yellow witches' broom is known on all native and introduced spruces across North America, but it is more common in the west. The alternate host of this rust is kinnikinnick or common bearberry (*Arctostaphylos uva-ursi* (L.) Spreng.).

Symptoms and Signs

This is the most conspicuous disease of spruce in the prairie provinces. Yellowish witches' brooms of different sizes can be recognized from a distance (Figs. 8A, B). Needles of the affected brooms die and are shed in the fall, leaving bare branches in winter and early spring. In the spring, systemically infected needles emerge on the brooms; small, dot-like spermogonia are produced on them, followed by orange-yellow, blister-like aecia (Fig. 8C). Affected needles are pale yellow. Witches' brooms increase in size every year, and big brooms 20 to 30 years old are common. On the alternate host kinnikinnick, deep-orange-colored telial sori are produced on the purple-brown spots on the underside of the leaves (Fig. 8D).

Disease Cycle

Powdery, yellow airborne aeciospores produced on spruce needles in early summer are carried to the current-year leaves of kinnikinnick and initiate infection. During the next spring, teliospores are produced on the underside of the second-year leaves. Urediniospores are not produced. Fragile basidiospores are produced in the spring as the result of teliospore germination and infect young shoots of spruce. Infections become systemic, and after several years the witches' brooms are produced as a result of the abnormal proliferation of short shoots every year. After spermogonia appear, aecia are produced every year on systemically infected needles produced on the broom.

Damage

Yellow witches' broom of spruce affects the shape of the crown, produces dead tops, and sometimes results in tree mortality. Damage caused by the disease in the prairie provinces has not been appraised but is considered insignificant.

Control

No control measure has been attempted for this disease.

Selected References

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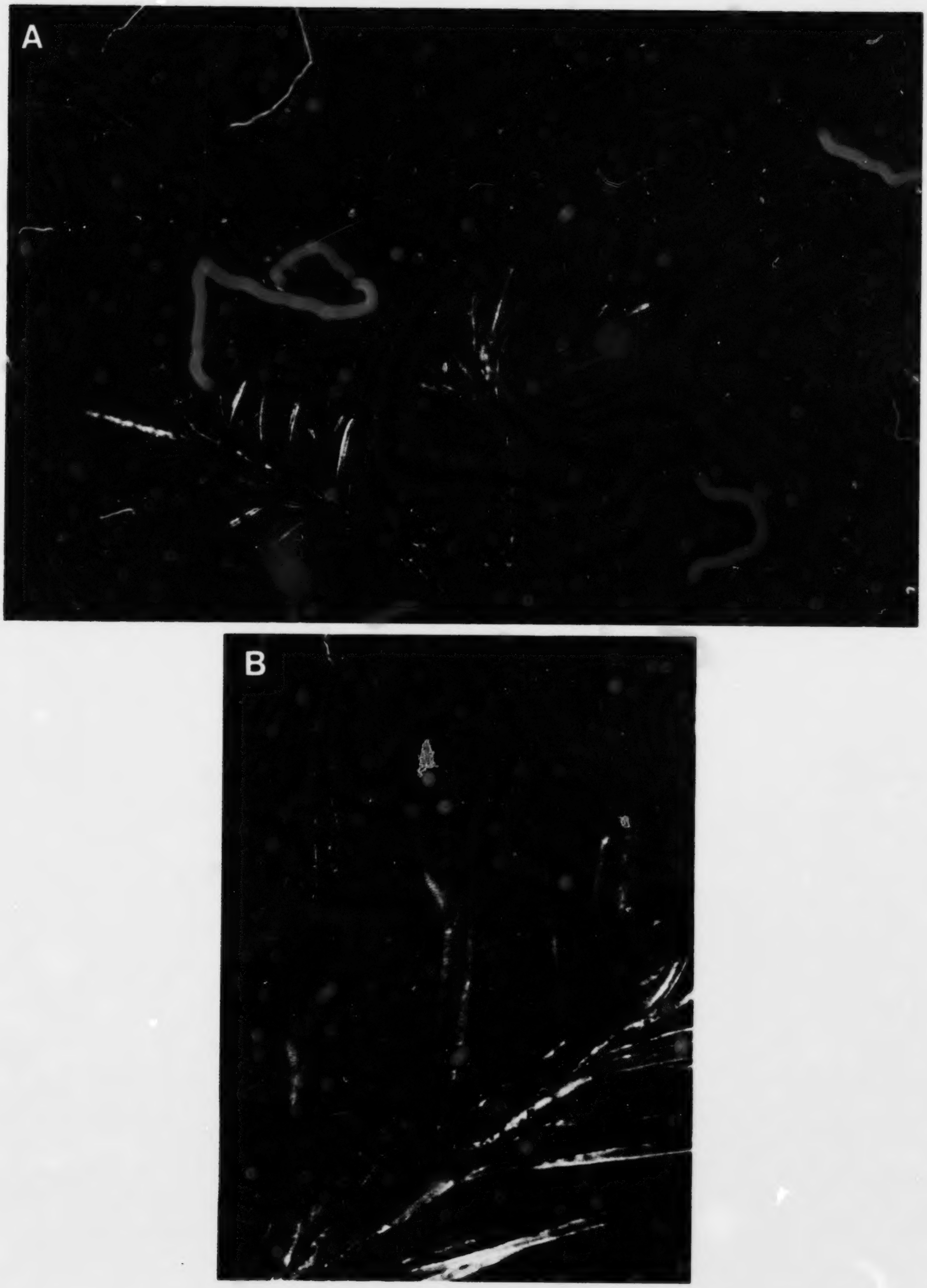
Ziller, W.G. 1978. The tree rusts of western Canada. Environ. Can., Can. For. Serv., Ottawa, Ont. Publ. 1329.

Figure 8. Yellow witches' broom of spruce (*Picea* spp.) caused by *Chrysomyxa arctostaphyli*. A. Distant view of a yellow witches' broom on white spruce, *Picea glauca*. **B.** A young broom on white spruce. **C.** Close-up of infected spruce needles showing spermogonia (blackish dots) and aecia (orange-yellow ridges). **D.** Alternate state (telia) on the lower surface of kinnikinnick, *Arctostaphylos uva-ursi*.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NEEDLE CASTS AND OTHER NEEDLE DISEASES OF FIR

Cause

Eight common needle casts and other needle diseases of fir (*Abies* spp.) that occur in the prairie provinces are listed in Table 3 (p. 26). They all belong to the class Ascomycetes. Needle rusts of fir are discussed separately (see Needle Rusts of Fir).

Distribution and Hosts

Two fir species occur in the prairie provinces: alpine fir (*Abies lasiocarpa* (Hook.) Nutt.), which occurs from western Alberta to British Columbia, particularly at higher elevations in the Rocky Mountains; and balsam fir (*A. balsamea* (L.) Mill.), found in the boreal forest zone of the three prairie provinces. The distribution of needle diseases of these two fir species within the region is not well known.

Symptoms and Signs

Symptoms and signs of needle diseases of fir vary depending on the species of pathogen and stage of the disease. Generally, discoloration and premature death of needles and the kind of fruiting structures are the important criteria for identification. Microscopic examination of proper spore states is necessary for definite identification; collections made during midsummer often lack mature spores, which makes identification difficult. Distinguishing characteristics are listed in Table 3.

Disease Cycle

In general, windborne ascospores produced on overwintered diseased needles, either on the tree or on the ground, infect newly formed needles in early summer. Fruiting structures may be visible during the growing season (Figs. 9A, B), but spores usually do not mature until the next spring.

Damage

Fir needle casts and other needle diseases seldom kill trees; however, severe infection can reduce the vigor of small trees and consequently can make the trees vulnerable to other pathogens. Heavy infection by any needle disease is undesirable for ornamental trees.

Control

No control measure is available or necessary for needle diseases of fir.

Selected References

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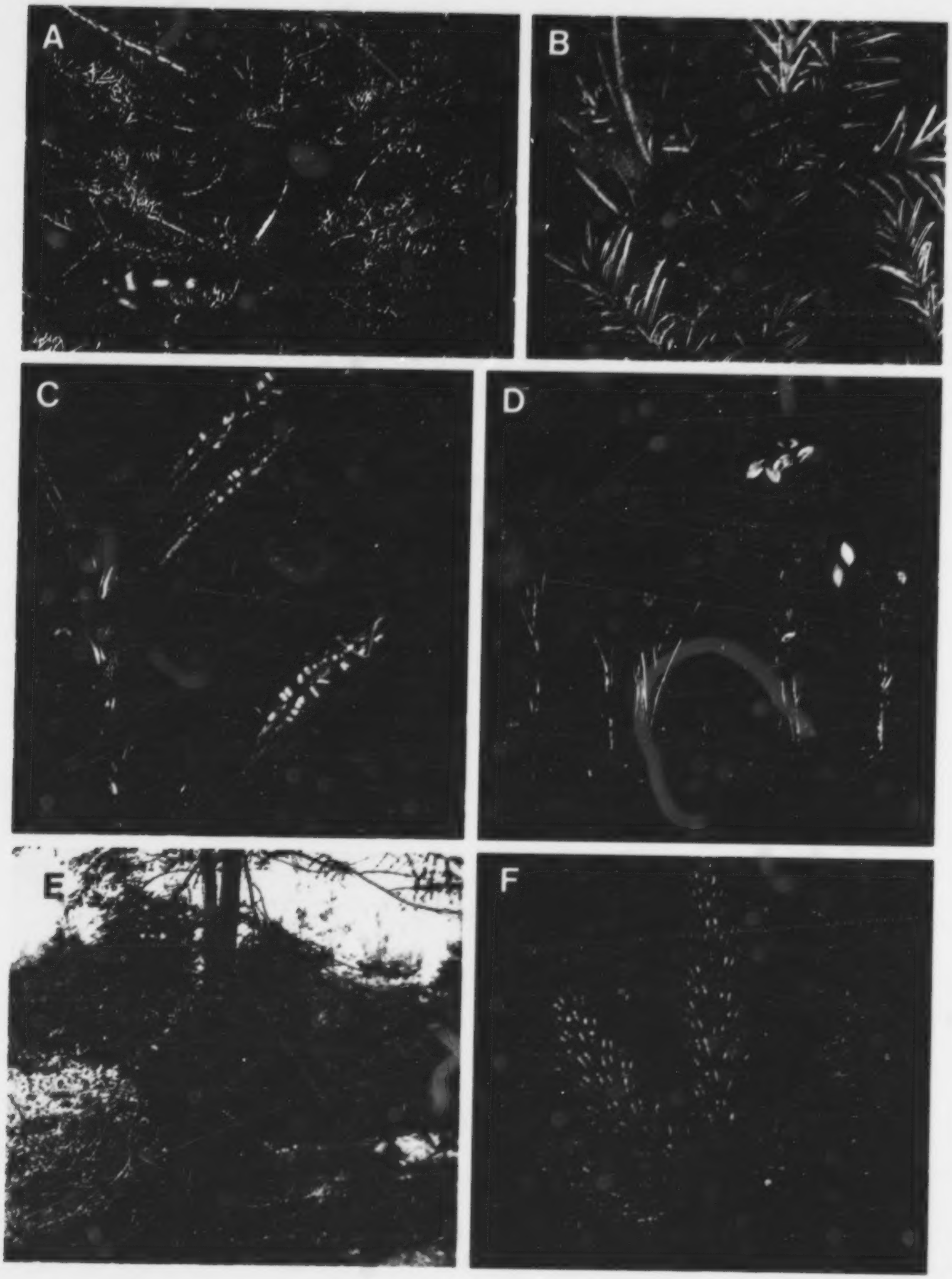
Darker, G.D. 1967. A revision of the genera of the Hypodermataceae. Can. J. Bot. 45:1399-1444.

Hunt, R.S.; Ziller, W.G. 1978. Host-genus keys to the Hypodermataceae of conifer leaves. Mycotaxon 6:481-496.

Figure 9. A needle cast, *Isthmiella abietis*, on alpine fir, *Abies lasiocarpa*. A. Straw-colored, infected second-year needles. **B.** Close-up of infected needles showing dark, continuous fruiting bodies (hysterothecia) along midribs.

Table 3. Symptoms and signs of common needle casts and other needle diseases of fir in the prairie provinces

Organism	Symptoms and signs
Isthmiella abietis (Dearn.) Darker ≡ *Bifusella abietis* Dearn. **Needle cast**	Hysterothecia on discolored needles, continuous along midrib, black; ascospores bifusoid, one-celled, hyaline, 40–50 × 4–6 μm, with gelatinous sheath, eight spores per ascus
Isthmiella quadrispora Ziller **Needle cast**	Hysterothecia on yellow, dead needles, continuous along midrib, black; ascospores bifusiform to biclavate, one-celled, 40–55 × 3–6 μm, with gelatinous sheath, four spores per ascus
Lirula abieti-concoloris (Mayer ex Dearn.) Darker ≡ *Hypodermella abieti-concoloris* Mayer ex Dearn. **Needle cast**	Hysterothecia on discolored needles, black or bluish black lustre, continuous along midrib; ascospores clavate, hyaline, one-celled, 70–104 × 4–5 μm, with gelatinous sheath (Figs. 9A, B)
Lophomerum autumnale (Darker) Magasi **Needle cast**	Hysterothecia scattered on both sides of needles, shiny black, roundish; ascospores filiform, up to four-celled, 85–95 × 1.5–2.0 μm, with gelatinous sheath
Nothophacidium abietinellum (Dearn.) Reid & Cain **Snow blight**	Disk-shaped apothecia, up to 0.8 mm in diameter, develop subepidermally and become exposed, on discolored needles; ascospores oval to broad-ellipsoid, 5.5–8.5 × 4.5–6.5 μm, hyaline, occasionally brown with age
Phacidium abietis (Dearn.) Reid & Cain **Snow blight**	Disk-shaped apothecia, up to 0.5 mm in diameter, arranged in linear series on each side of the midrib, intrahypodermal on discolored needles; ascospores ellipsoid to fusiform, curved, hyaline, 17–25 × 5–7 μm
Phaeocryptopus nudus (Pk.) Petr. **Needle fungus**	Globose, black fruiting bodies (pseudothecia), up to 1 mm, scattered on the surface of discolored needles; ascospores slightly clavate, hyaline to pale brown, two-celled, 10–15 × 4–5 μm
Sarcotrochila balsameae (Davis) Korf ≡ *Stegopezizella balsameae* (Davis) Syd. **Snow blight**	Disk-shaped apothecia, up to 0.5 mm in diameter, on the underside of discolored needles; ascospores ovoid, hyaline, first one-celled, 10–25 μm, becoming brown and four-celled, 24–30 × 7–10 μm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NEEDLE RUSTS OF FIR

Cause

Six species of fir needle rust are common in the prairie provinces: *Hyalopsora aspidiotus* P. Magn., *Melampsora abieti-capraearum* Tub., *Pucciniastrum epilobii* Otth (Figs. 10A, B), *P. goeppertianum* (Kuehn) Kleb. (Figs. 10C, D), *Uredinopsis phegopteridis* Arth., and *Melampsorella caryophyllacearum* Schroet. (Figs. 10E, F).

Distribution and Hosts

Distribution of each species within the region is not well known. All species of fir needle rust are heteroecious, that is, they need alternate hosts to complete their life cycles. Alternate hosts for each species are as follows:

H. aspidiotus—oak fern (*Gymnocarpium dryopteris* (L.) Newm.);
Melampsora abieti-capraearum—willow (*Salix* spp.);
P. epilobii—fireweed (*Epilobium angustifolium* L.) (Fig. 10B);
P. goeppertianum—blueberry and huckleberry (*Vaccinium* spp.) (Fig. 10D) and cranberry (*V. vitis-idaea* L.);
U. phegopteridis—oak fern (*G. dryopteris*);
Melampsorella caryophyllacearum—chickweed (*Cerastium* spp. and *Stellaria* spp.).

Symptoms and Signs

Infected needles are often chlorotic or discolored (yellow, brown) or become chlorotic and shed prematurely. Small, dot-like spermogonia and yellowish-orange or white cup-shaped aecia (Fig. 10C) with powdery aeciospores are produced on the undersides of needles. *Melampsorella caryophyllacearum* causes conspicuous witches' broom symptoms (Fig. 10E) similar to yellow witches' broom of spruce.

Disease Cycle

The typical disease cycle of a fir needle rust, exemplified by *P. epilobii*, is as follows. The pathogen overwinters in cushion-shaped fruiting bodies (telia) on dead leaves of fireweed. In the spring, teliospores germinate to produce fragile, windborne basidiospores. They infect newly produced fir needles. In a few weeks minute, dot-like sexual fruiting structures (spermogonia) are produced. They are followed by cup-shaped aecia containing powdery, yellow aeciospores. These spores infect leaves of fireweed and produce a repeating spore state (uredinia) with powdery spores (urediniospores); later, cushion-shaped, dark-colored telia are formed. Disease cycles of other needle rusts of fir are similar to that of *P. epilobii*. In *M. caryophyllacearum*, however, infection on fir is perennial. It survives systemically on expanding witches' broom tissues. Spermogonia and aecia are produced annually on newly formed needles on the witches' broom.

Damage

Only *P. epilobii* is known to cause any significant damage in the prairie provinces. Young alpine fir (*Abies lasiocarpa* (Hook.) Nutt.) are often heavily infected with this species. All current-year needles can be infected, and growth of trees is apparently inhibited if heavy infections occur in successive years. Heavily infected trees are usually not killed, however, and recover from the effect of the rust in a few years. After trees reach a height of 2 m or more, impact of the rust becomes insignificant. Two species, *P. goeppertianum* and *M. caryophyllacearum*, are known to cause economic damage to Christmas tree plantations in the Maritime provinces. The western form of *P. goeppertianum* that exists in the Rocky Mountains is different from the eastern form; it does not cause any damage to needles because of the slow development of aecia.

Control

No control measure is recommended for needle rusts of fir in this region, but protective fungicide spray or alternate host eradication are considered effective if the need arises.

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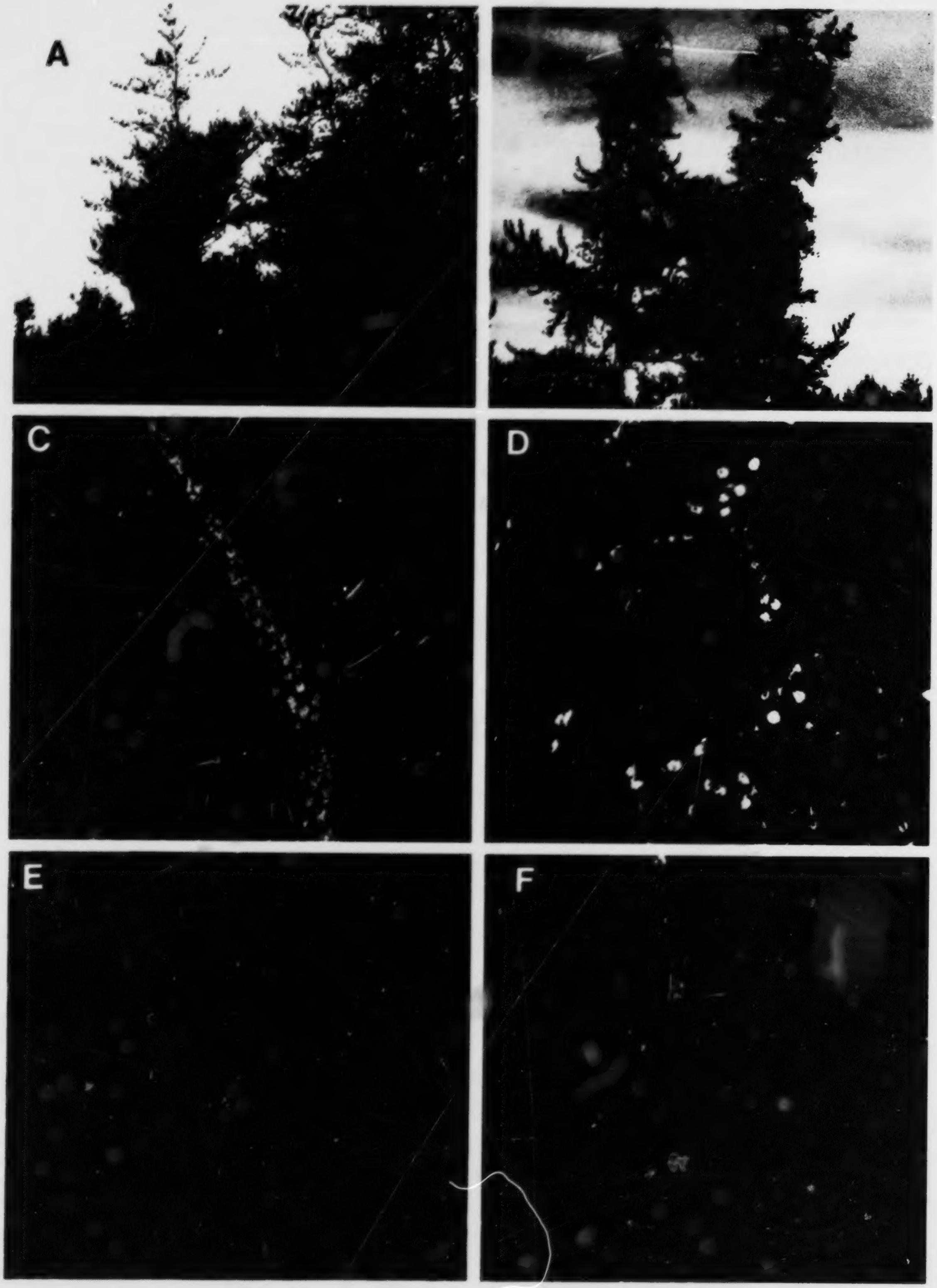
Figure 10. Fir needle rusts. A, B. *Pucciniastrum epilobii*. **A.** Heavily infected alpine fir, *Abies lasiocarpa*. **B.** Infected alpine fir and fireweed, *Epilobium angustifolium*, the alternate host, showing uredinia and telia. **C, D.** *Pucciniastrum goeppertianum*. **C.** Infection on alpine fir, showing elongated horn-like aecia. **D.** Swollen, brown, infected stems with telia and an uninfected alternate host (far right), grouseberry, *Vaccinium scoparium*. **E, F.** *Melampsorella caryophyllacearum*. **E.** A witches' broom caused by the rust on balsam fir, *A. balsamea*. **F.** Close-up of infected branchlets with ridges of yellow aecia.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DWARF MISTLETOES

Cause

Lodgepole pine dwarf mistletoe (*Arceuthobium americanum* Nutt. ex Engelm.) is a parasitic flowering plant belonging to the family Loranthaceae. A related dwarf mistletoe (eastern dwarf mistletoe, *A. pusillum* Pk.) is common on black spruce (*Picea mariana* (Mill.) B.S.P.) in Manitoba and the eastern edge of Saskatchewan, but this species is economically not as important as *A. americanum*.

Distribution and Hosts

Distribution of lodgepole pine dwarf mistletoe in Canada extends from the Coast Range in British Columbia to the Manitoba-Ontario border. The two main hosts of the pathogen are lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and jack pine (*Pinus banksiana* Lamb.), but it is also occasionally found on white spruce (*Picea glauca* (Moench) Voss) and Scots pine (*Pinus sylvestris* L.) as well as several other pine species (*Pinus albicaulis* Engelm., *P. edulis* Engelm., *P. flexilis* James, *P. jeffreyi* Grev. & Balf., and *P. ponderosa* Laws.).

Symptoms and Signs

The most conspicuous symptom of dwarf mistletoe infection is the production of witches' brooms (Figs. 11A, B). The size and shape of the brooms vary depending on the host species and the age and position of the infection. Witches' brooms on jack pine (Fig. 11A) tend to be much larger and more open than those on lodgepole pine (Fig. 11B). Infected branches are usually twisted and produce spindle-shaped swellings (Fig. 11C). Dwarf mistletoe is dioecious (having separate male and female plants). Aerial shoots of dwarf mistletoe are greenish yellow and up to 10 cm long and consist of branch segments with reduced scale-like leaves. Depending on the sex of the plant, they produce male (Fig. 11D) or female (Fig. 11E) flowers during late spring or early summer. After pollination, berries are produced on female plants in the summer and remain on the plant for about a year before they ripen (Fig. 11F). When aerial shoots become nonfunctional, they fall off and leave basal cups, which stay for several years. The basal cups are connected to the endophytic system of the dwarf mistletoe in the pine tissue and are important diagnostic features of dwarf mistletoe, because witches' brooms and swellings of the stem can also result from many other causes and fresh aerial shoots are often absent.

Disease Cycle

The single, large seed in a berry is forcefully discharged during mid-August to mid-September. The speed of discharge has been measured at approximately 25 m/s, and the seed has been known to fly up to 15 m. The seed is surrounded by a hygroscopic, sticky material called viscin that enables it to adhere to the surface on which it lands. When seeds land on susceptible host tissue they overwinter, germinate in May or June, and penetrate the host. Young twigs are most susceptible. It takes about 3 to 5 years before the infection produces aerial shoots. Flower and seed production usually begins 1 to 2 years after the shoots first appear.

Damage

This disease causes the largest amount of annual loss in merchantable lodgepole and jack pines in the prairie provinces. Heavily infected young trees will not reach merchantable size. Dwarf mistletoe not only causes mortality but also reduces growth by about one-third. Dwarf mistletoe is particularly damaging to immature stands up to 50 years old. The unsightly appearance of the infected trees due to brooming is also a serious concern in townsites and parks.

Control

Because of the limited seed dispersal distance and slow rate of buildup of the disease, silvicultural control measures such as elimination of infected residual trees (particularly those close to young stands) and clear-cutting of all infected trees in isolated infection centers are effective and economically feasible. Planting of nonhost tree species in high risk areas is recommended.

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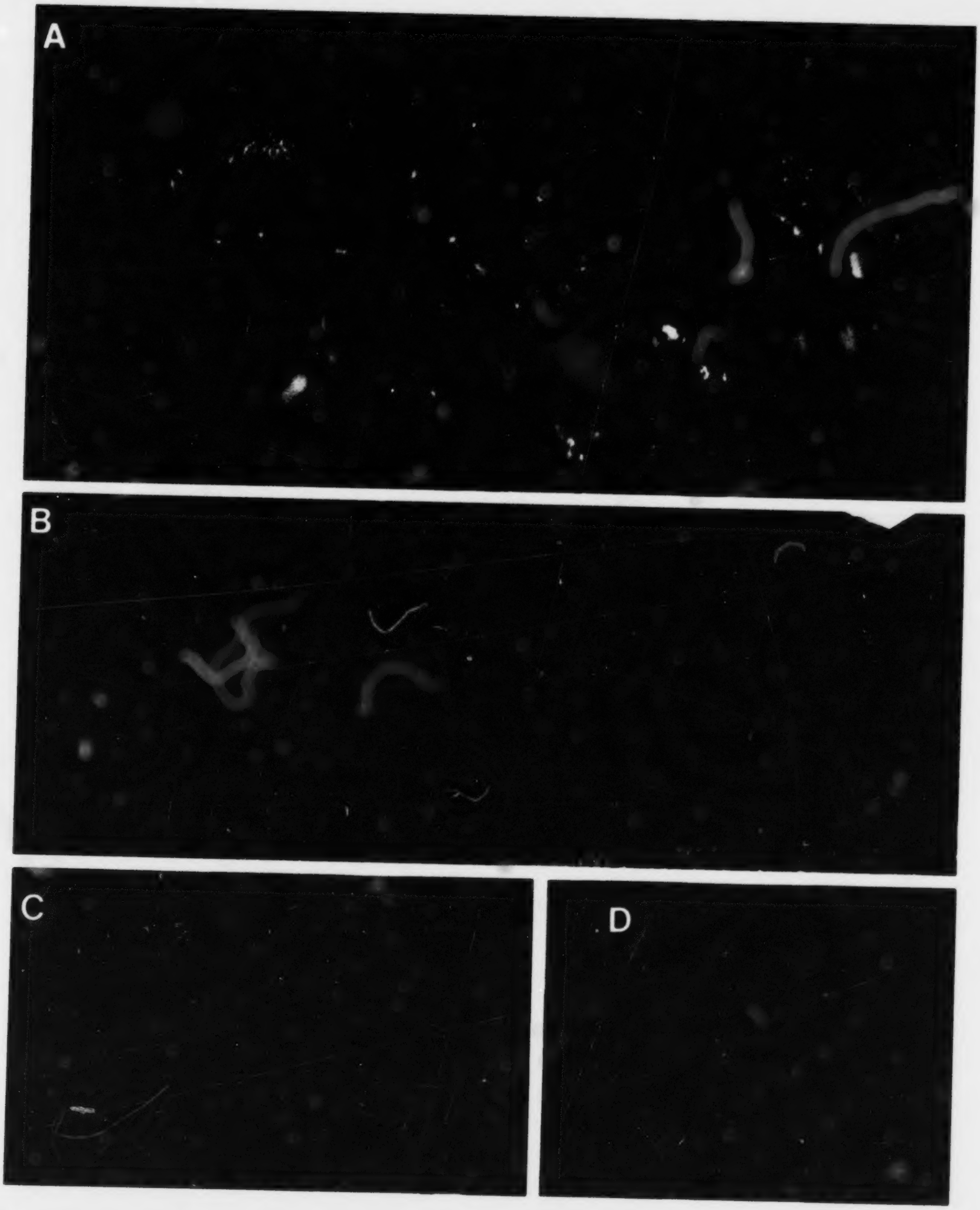
Figure 11. ***Arceuthobium americanum*, dwarf mistletoe of hard pines (*Pinus* spp.). A.** Heavily infected jack pine, *Pinus banksiana*. **B.** Two heavily infected lodgepole pines, *P. contorta* var. *latifolia*, with conspicuous witches' broom symptoms. **C.** Aerial plants and spindle-shaped swelling of infected stem of lodgepole pine. **D.** Close-up of male flowers. **E.** Close-up of female flowers. **F.** Mature berries.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MORTALITY OF LODGEPOLE PINE ASSOCIATED WITH MOUNTAIN PINE BEETLE

Cause

The mountain pine beetle (*Dendroctonus ponderosae* Hopk.) (Fig. 12A) causes death of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) in two ways: by transmitting several species of blue stain fungi (*Ceratocystis* spp.) and by girdling the living bark. Three main species of blue stain fungi that are consistently present and associated with mountain pine beetle attack are *Ceratocystis clavigera* (Robins.-Jeff. & Davids.) Upad., *C. minor* (Hedgc.) Hunt, and *C. huntii* Robins.-Jeff. The three fungi belong to the class Ascomycetes. These fungi are considered to be responsible for stopping water transport in the main stem and killing the infected trees. For that reason this chapter is included here.

Distribution and Hosts

Mountain pine beetle damage is common and widespread across western North America; in Canada it occurs mainly in British Columbia. In 1977 several small patches of infested trees were recognized in the southwestern corner of Alberta. The infestations spread steadily every year, and the outbreak peaked in 1983 but declined drastically in 1984 and 1985. Before this outbreak the only recorded occurrence on the east side of the Rockies in Canada was during 1940–44 in Banff National Park. The main host of the mountain pine beetle in Alberta is lodgepole pine, but the insect has also been recorded on whitebark pine (*P. albicaulis* Engelm.) and limber pine (*P. flexilis* James) at higher elevations and on planted ponderosa pine (*P. ponderosa* Laws.) and Scots pine (*P. sylvestris* L.). Major hosts known in other regions are western white pine (*P. monticola* Dougl.) and ponderosa pine. Spruce (*Picea* spp.) and Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) are also known to be attacked, but they are not suitable hosts and broods rarely develop on them.

Symptoms and Signs

Needles of trees attacked in midsummer by the mountain pine beetle usually remain green during the winter. The next summer the foliage discolors, turing first yellow and then reddish brown (Fig. 12B). The reddish brown color may remain during the third year, before the dead foliage turns grayish brown. Grayish blue staining of sapwood is the most conspicuous symptom of colonization by blue stain fungi. Hyphae of blue stain fungi colonize mainly in ray parenchyma cells. The symptom is best observed in cross sections of trees attacked by bark beetles (Figs. 12C, D). Various fungal fruiting structures (such as synnemata and perithecia) and mycelium of blue stain fungi and other fungi are often evident in beetle galleries and pupal chambers.

Disease Cycle

The adult beetles attack trees in midsummer by chewing through the outer bark and making vertical parent galleries (tunnels) just outside of the cambial layer. Eggs are laid along the galleries. Upon hatching, the larvae feed circumferentially and usually overwinter as late instar larvae or pupae. In late spring to early summer, pupae transform into adult beetles and emerge to attack new trees. The adult beetles carry a number of microorganisms, including blue stain fungi into newly infected trees. Fungal spores are known to be carried on the surface of the beetle and within a specialized sac (mycangium) located in the mouth area.

Damage

The mountain pine beetle is the most serious enemy of mature pines in western Canada. It has been estimated that between 1977 and 1985 a cumulative total of more than 1 million cubic metres of lodgepole pine were killed in Alberta. The monetary loss may be far greater than indicated by the volume loss because high-value mature trees are preferred by the beetles. In addition to direct volume loss, outbreaks of mountain pine beetle upset harvesting plans, reduce aesthetic value in recreational areas, and increase fire hazard.

Sapwood from salvaged trees killed by the mountain pine beetle may have variable amounts of blue stain and extensive checking, both of which lower the commercial value of trees for use as saw wood and pulp.

Continued on next page.

Figure 12. Mortality of lodgepole pine (*Pinus contorta* var. *latifolia*) associated with the mountain pine beetle, *Dendroctonus ponderosae*. A. An adult (female) mountain pine beetle. B. Mortality of lodgepole pine in southern Alberta (1980). C. A cross section of an infected log developing blue-stained sapwood caused by blue stain fungi, *Ceratocystis* spp. D. Cross sections of infected logs with various patterns of blue staining of sapwood.

Control

Preventive management is the most satisfactory approach to reducing losses from the mountain pine beetle in lodgepole pine forests. The following management options can be considered: (1) shortened rotation, (2) type conversion, (3) mixed species stands, (4) age and species mosaics, (5) partial cuts, and (6) stocking control. For ongoing epidemic situations, sanitation salvage logging is often recommended because it utilizes timber that would be worthless in a short time and reduces the number of beetles and their potential food source. In certain situations direct control measures such as application of insecticides, felling and burning, or trapping of beetles with attractants may be helpful to protect high-value trees or trees in designated areas.

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BURLS OF SPRUCE AND PINE

Cause

The cause of burls of spruce (*Picea* spp.) and pine (*Pinus* spp.) is not known; however, certain infectious agents such as bacteria, viruses, and mycoplasma together with insects are suspected as the causal agents.

Distribution and Hosts

Burls are common on white and Engelmann spruces (*Picea glauca* (Moench) Voss and *P. engelmannii* Parry), especially at higher elevations in the Canadian Rockies. Occasional burls of similar nature are also found on lodgepole and jack pines (*Pinus contorta* Dougl. var. *latifolia* Engelm. and *P. banksiana* Lamb.).

Symptoms and Signs

Trees with burls often occur in clusters, and multiple burls on one tree are common. Globose or semiglobose galls are produced on the main stems and branches of spruce (Figs. 13A, B) and pine. Gall tissues are usually sound, and no decay or stain is associated with the burls. For this reason many burls of spruce have been used ornamentally for artistic sign posts and other structures (Figs. 13C, D). On hard pines, burls or globose galls are also produced by western gall rust, but galls caused by the rust produce orange spores in May to July; characteristics of bark and gall tissues are also different (see Western Gall Rust). Burls are usually initiated early in the growth of the stem and most of the time can be traced back to a single cell or small group of cells in the first year of growth.

Damage

Trees with burls seem to grow normally, but multiple main stem burls cause inconvenience in the debarking process and produce inferior milling products.

Control

Because the cause is not known, no control measure has been considered.

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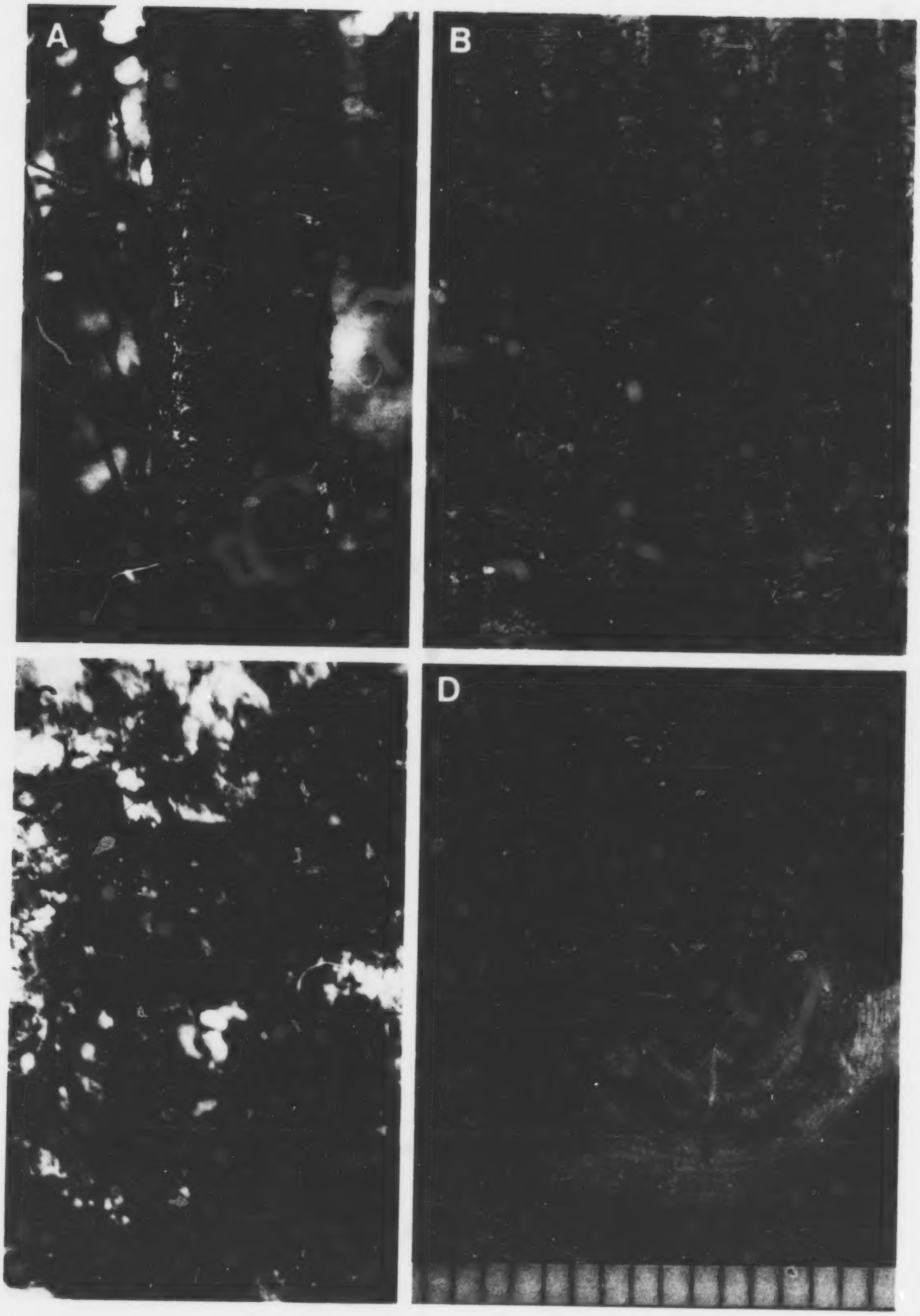
Figure 13. Burls of spruce (*Picea* spp.) and pine (*Pinus* spp.). A. An Engelmann spruce, *Picea engelmannii*, with numerous burls. **B.** Close-up of a burl. **C.** A multiple-burled spruce log used for a sign post. **D.** Multiple-burled spruce logs used for the gate of a ranch.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ATROPELLIS CANKER OF PINE

Cause

Atropellis canker of pine (*Pinus* spp.) is caused by the fungus *Atropellis piniphila* (Weir) Lohman & Cash, belonging to the class Ascomycetes.

Distribution and Hosts

This disease is found mainly in western North America (British Columbia, Alberta, Montana, Idaho, Washington, Oregon, Arizona, and New Mexico), although it has also been reported from Alabama and Tennessee. The occurrence of this disease is sporadic in most of the area, but in Alberta it is widespread over most of the range of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and has a high incidence in several areas. Other known hosts of this fungus are ponderosa pine (*P. ponderosa* Laws.), western white pine (*P. monticola* Dougl.), and whitebark pine (*P. albicaulis* Engelm.).

Symptoms and Signs

The first external symptom of Atropellis canker is the exudation of resin from the bark surface. Resin flow increases as the canker enlarges. Sunken elongated cankers on one side of the trunk, with evidence of resin flow, are the typical symptoms of this disease (Figs. 14A, B). Circumference growth of a canker is very slow, but it may eventually girdle and kill small trees. Large trees can be girdled only when several cankers are involved. On the center area of old cankers, small (up to 5 mm in diameter), black disk-shaped apothecia (Fig. 14C) and black spherical pycnidia appear, which permit a positive identification. When the fungus invades the xylem tissues of the tree, it causes blue-black discoloration of the wood (Fig. 14D).

Disease Cycle

Airborne ascospores, which are produced in disk-shaped apothecia during the growing season of the host trees, are responsible for the spread of the disease. Infection occurs mainly at the branch nodes. Apothecia are produced 2 to 4 years after infection, and new ones are formed every year.

Damage

Atropellis canker is considered to be one of the most important diseases of lodgepole pine in Alberta. The heavy resin flow results in a debarking problem that can increase costs of processing and can degrade pulp. Discoloration of wood caused by the disease degrades lumber and adds to the cost of bleaching in the pulping process. The effect of this disease on tree growth is not clearly known, but obvious deformation of main stems must affect growth rate of infected trees. Mortality is not common.

Control

Removal of all old infected trees near regeneration can reduce the number of new infections. Thinning before age 15, especially in dense stands, is recommended as an effective preventive measure. Clear-cutting of heavily infected stands is advisable to protect surrounding regenerations from infection.

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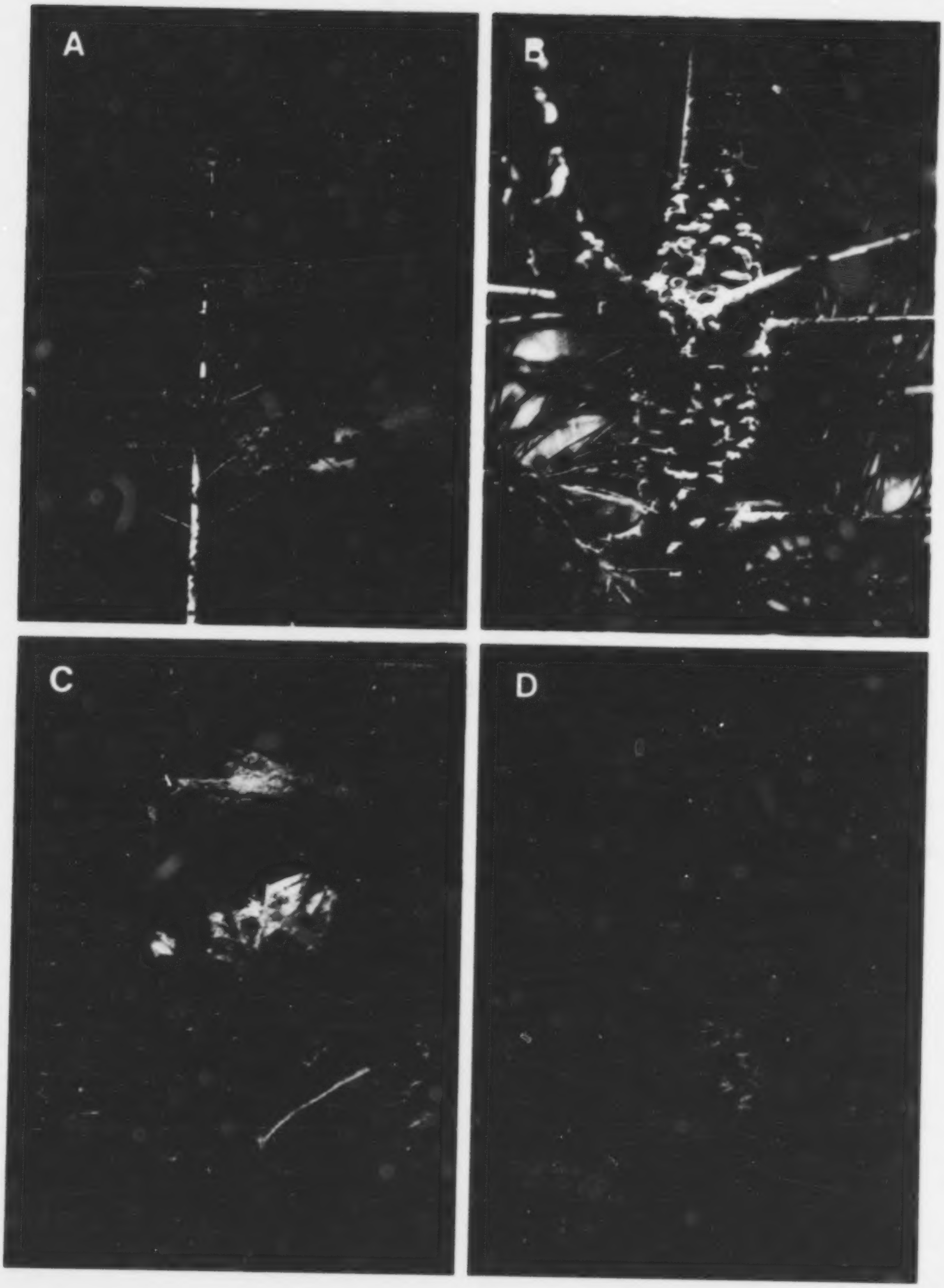
Figure 14. Atropellis canker of pine (*Pinus* spp.) caused by *Atropellis piniphila*. A. Close-up of a canker on lodgepole pine, *Pinus contorta* var. *latifolia*. **B.** A stand of lodgepole pine with many infected trees. **C.** Black fruiting bodies (apothecia) of *A. piniphila*. **D.** Cross section of an infected stem showing black discoloration of wood.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WHITE PINE BLISTER RUST

Cause

White pine blister rust is caused by the rust fungus *Cronartium ribicola* J.C. Fisch.

Distribution and Hosts

White pine blister rust is the most destructive disease of white pines (five-needle pines) in North America, Europe, and Asia. In the prairie provinces the hosts of this rust are whitebark pine (*Pinus albicaulis* Engelm.) (Figs. 15A, B) and limber pine (*P. flexilis* James) at high elevations in the Rocky Mountains and eastern white pine (*P. strobus* L.) in eastern Manitoba. Alternate hosts are many species of gooseberry and currant belonging to the genus *Ribes* (Figs. 15C, D). The rust occurs on alternate hosts beyond the range of infected pines.

Symptoms and Signs

Elongated cankers (Fig. 15B) girdle the stem and eventually kill the tree beyond the cankers, thus causing spiketop or flagging symptoms (Fig. 15A). On alternate hosts (*Ribes* spp.) dome-shaped uredinia, containing urediniospores, and column-shaped telia, composed of appressed teliospores, are produced (Fig. 15C). Another rust on *Ribes* spp., *Puccinia caricina* DC., is often confused with *C. ribicola*, but it produces clusters of cup-shaped aecia rather than the dome-shaped uredinia or column-shaped telia of *C. ribicola*.

Disease Cycle

Fragile, windborne spores (basidiospores) produced on alternate host plants initiate the infection on pine through the needles, and then it grows into the stems. Elongated cankers develop, and one to several years after infection spermogonia with sweet droplets containing sexual spores (spermatia) are produced; later, aecia break through the bark. Powdery, orange-yellow aeciospores are released from the blisters. The aeciospores are windborne and infect alternate hosts but are incapable of reinfecting pine. Within a few weeks, small dome-shaped, spore-producing uredinia are formed, and urediniospores produced in them can reinfect alternate host leaves. Later, columnar or hair-like structures called telia are produced that consist of aggregations of teliospores. Basidiospores are produced upon germination of teliospores.

Damage

White pine blister rust kills white pines of all ages and sizes and is considered to be one of the most destructive tree diseases in North America. Because of the scarcity of hosts, the disease is not economically important in the prairie provinces, except in eastern Manitoba, where it is found on eastern white pine. Limber and whitebark pines in the Rocky Mountains are heavily infected, but the trees are not economically important.

Control

The two control measures considered to be practical against this disease are silvicultural control, especially pruning of lower branches (up to 1.5 m), and breeding of disease-resistant cultivars. Eradication of alternate hosts (*Ribes* spp.) was considered a logical method of control of the disease but did not work in several trials in western North America. Extensive trial applications of systemic fungicides have been made, but the early promise shown by them has not materialized.

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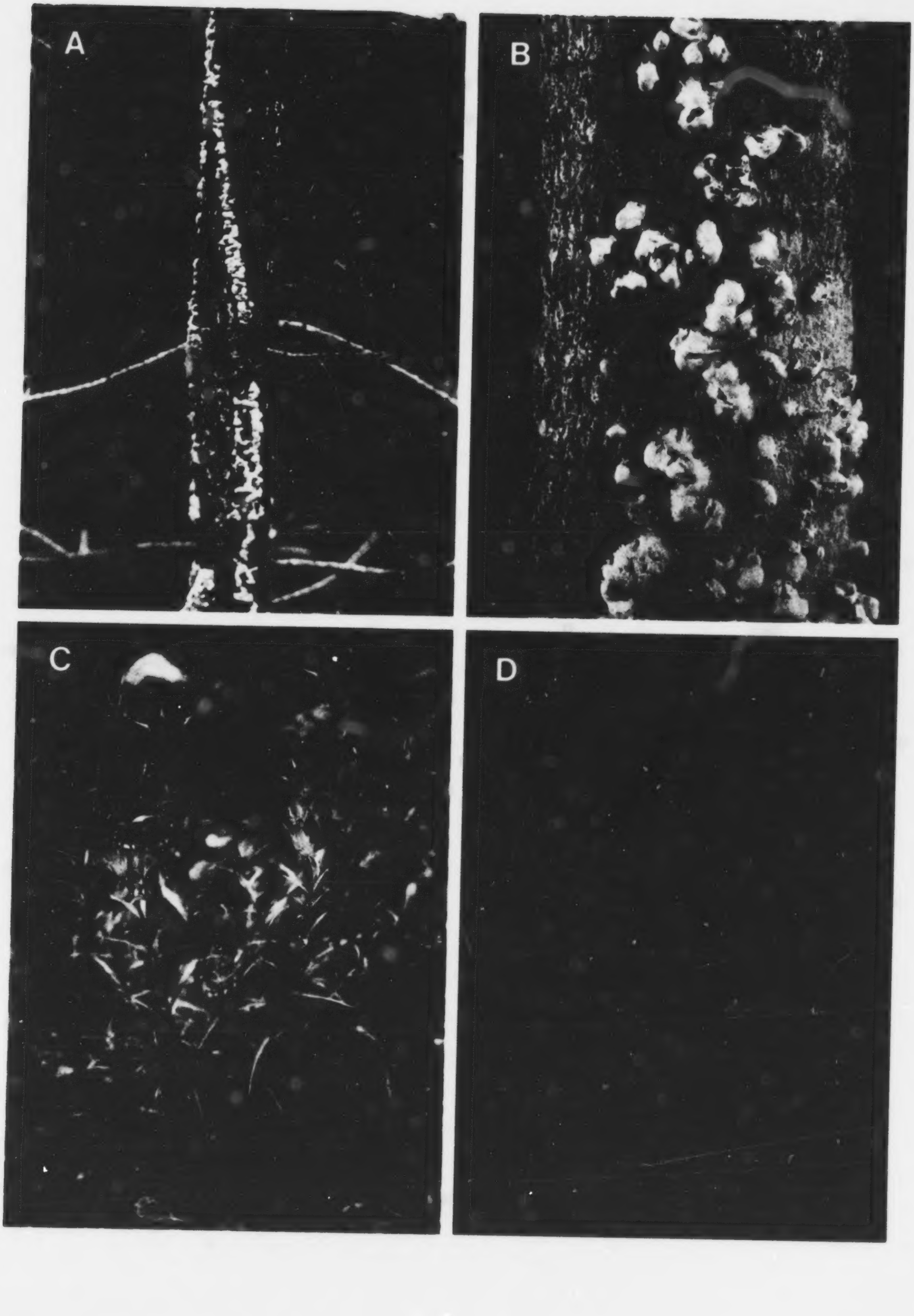
Figure 15. White pine blister rust, *Cronartium ribicola*. A. An infected whitebark pine, *Pinus albicaulis*, showing a spiketop symptom. **B.** A typical canker on young whitebark pine. **C.** Bristly black currant, *Ribes lacustre*, with uredinia and telia. **D.** A common alternate host, wild black currant, *R. hudsonianum*.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STALACTIFORM BLISTER RUST OF HARD PINES

Cause

Stalactiform blister rust of hard pines (*Pinus* spp.) is caused by a rust fungus, *Cronartium coleosporioides* Arth. The name *C. coleosporioides* has been used for a group of organisms that includes western gall rust (*Endocronartium harknessii* (J.P. Moore) Y. Hiratsuka (≡ *Peridermium harknessii* J.P. Moore)), limb rust (*C. filamentosum* Hedgc.), and the fungus concerned here; however, the name should be applied only to the organism causing stalactiform blister rust. An albino form of this rust that lacks yellow pigment in the cytoplasm of all spore states is found in Banff National Park. That fungus has been named *C. coleosporioides* Arth. f. *alba* Ziller.

Distribution and Hosts

This rust is found throughout Canada, from Nova Scotia to British Columbia and the Yukon, and it is particularly prominent in western Canada. Distribution extends southward into the Lake States and in the west to Colorado, Utah, and southern California. In Canada, major hosts of this rust are lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and jack pine (*P. banksiana* Lamb.), but it is also found on ponderosa pine (*P. ponderosa* Laws.), mugo pine (*P. mugo* Turra), Scots pine (*P. sylvestris* L.), and shortleaf pine (*P. echinata* Mill.). In the United States four additional pine species have been reported as hosts of this rust: Aleppo pine (*P. halepensis* Mill.), Coulter pine (*P. coulteri* D. Don), Jeffrey pine (*P. jeffreyi* Grev. & Balf.), and knobcone pine (*P. attenuata* Lemm.). Indian paint-brush (*Castilleja* spp.) and cow-wheat (*Melampyrum lineare* Desr.) are the main alternate hosts. Other known hosts for the rust are yellow owl-clover (*Orthocarpus luteus* Nutt.), lousewort (*Pedicularis bracteosa* Benth.), and yellow rattle (*Rhinanthus minor* L. = *R. crista-galli* L.).

Symptoms and Signs

A slight swelling of the bark, resulting in a spindle-shaped stem, and production of orange-yellow aeciospores in early summer are the characteristic symptoms and signs of the disease on small stems. On trunks of older trees, cankers are elongated, diamond-shaped, and often sunken; they spread much faster longitudinally than laterally (Figs. 16A, B). Cankers are made up of three distinct zones: the innermost old inactive zone, where sporulation occurred in previous years; the middle zone, where aeciospore sporulation is occurring; and the outer zone, where the fungus is advancing. On alternate host plants, uredinia and telia are produced in discolored zones on the underside of leaves. The uredinia are minute, dome-shaped structures containing urediniospores; the telia are hair-like structures that produce teliospores.

Disease Cycle

Fragile basidiospores produced on the alternate host plants are airborne and infect unwounded young pine shoots. Infection occurs in late summer, and cankers develop within 2 years after infection. After the production of spermogonia during an inconspicuous sexual state, characteristic powdery, orange-yellow aeciospores are produced. In western Canada aeciospore production continues from late May to the middle of July. Aeciospores are carried by the wind, and when they land on alternate host leaves (Fig. 16C) they may initiate infections. Approximately 2 weeks after infection uredinia appear, and when they are mature they rupture and release urediniospores. Airborne urediniospores reinfect alternate hosts, thereby repeating this state several times in one season. Later in the season, teliospores are produced on the alternate host (Fig. 16D), and upon germination they produce basidiospores that infect pine.

Damage

Susceptible pines of all ages are affected by stalactiform blister rust, but the greatest mortality occurs among seedlings and saplings whose main stems are killed by girdling. Isolated incidents of significant damage have also been reported in young dense stands, nurseries, and tree farms in western Canada.

Control

No serious attempt has yet been made to control this disease, but economic losses in nurseries can be minimized under certain conditions by elimination of alternate host plants and the use of a protective fungicide spray.

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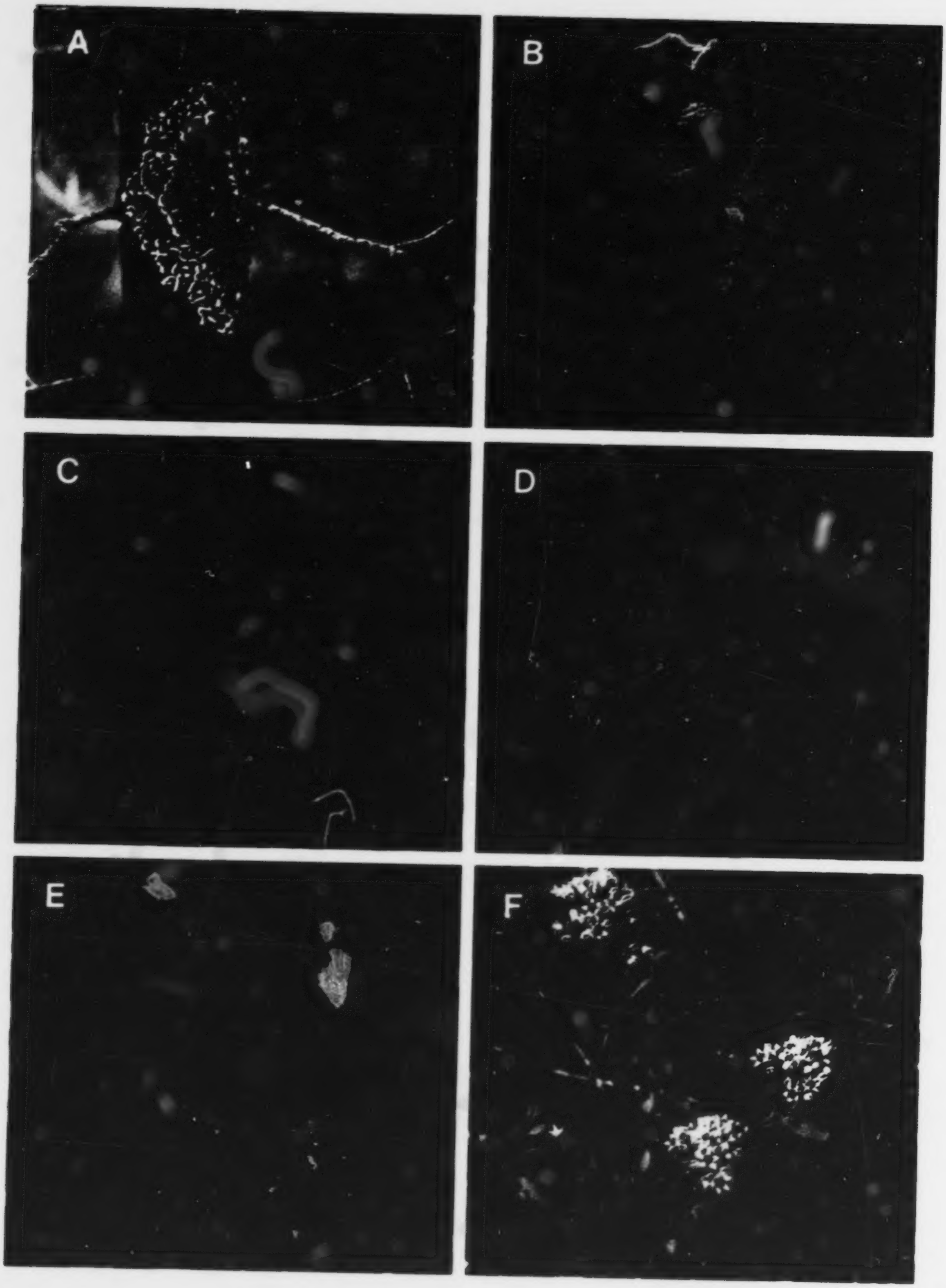
Figure 16. Stalactiform blister rust of hard pines (*Pinus* spp.) caused by *Cronartium stalactiforme*. A. A typical elongated diamond-shaped canker on lodgepole pine, *Pinus contorta* var. *latifolia*. **B.** Close-up of a canker. **C.** A common alternate host, Indian paint-brush, *Castilleja miniata*. **D.** Horn-like telia on Indian paint-brush.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COMANDRA BLISTER RUST OF HARD PINES

Cause

Comandra blister rust of hard pines (*Pinus* spp.) is caused by a rust fungus, *Cronartium comandrae* Pk.

Distribution and Hosts

Comandra blister rust is found across Canada, from New Brunswick to the Yukon, and southward to Tennessee, Alabama, Mississippi, New Mexico, and California. Major hosts of this rust in the prairie provinces are lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and jack pine (*P. banksiana* Lamb.), but it is also known on introduced pines such as ponderosa pine (*P. ponderosa* Laws.), mugo pine (*P. mugo* Turra), and Scots pine (*P. sylvestris* L.). Two common alternate hosts for this disease in the prairie provinces are bastard toad-flax (*Comandra umbellata* (L.) Nutt. var. *pallida* (DC.) M.E. Jones) and northern bastard toad-flax (*Geocaulon lividum* (Richards.) Fern). The rust often occurs on alternate hosts well beyond the range of infected pines.

Symptoms and Signs

Conspicuous swelling of the bark, resulting in spindle-shaped stems, and production of orange-yellow aeciospores are the characteristic symptoms and signs of the disease on small branches. On larger stems, cankers are circular in shape and grow laterally as much as longitudinally (Figs. 17A, B), thus girdling stems much faster than cankers produced by stalactiform blister rust (*C. coleosporioides*), which tends to spread much faster longitudinally than laterally. Girdled stems above the infections often cause spiketops in older stands. This is the only species of pine stem rust that has aeciospores with elongated and pointed ends rather than subglobose spores. Infections of this rust on nursery seedlings have often been confused with infections of western gall rust, since both cause similar swellings of stems; however, they can be distinguished by examining whether swellings are mainly of wood (western gall rust) or bark (comandra blister rust).

Disease Cycle

Basidiospores produced on the alternate host plants are airborne and infect young pine shoots. The infection occurs in late summer, and cankers develop within 2 years after infection. After an inconspicuous sexual state (spermogonia), characteristic orange-yellow aeciospores are produced. Depending on the location, aeciospores are produced from late May to the middle of July. They are carried by the wind and infect leaves of alternate hosts. Powdery, yellow urediniospores are produced on alternate hosts and reinfect alternate hosts. This state can be repeated several times in one season. Later in the season, columns or horns of teliospores are produced on the alternate host (Figs. 17C–F), and upon germination they produce basidiospores.

Damage

Because of the rapid lateral growth of the canker of comandra blister rust, this rust girdles and kills stems much faster than other species of pine stem rust such as stalactiform blister rust or sweet fern blister rust. Bare-root nursery seedlings are often infected by comandra blister rust.

Control

No serious attempt has yet been made to control this disease, but economic losses can be minimized by fungicides or by eradication of alternate hosts in or around nursery beds of bare-root seedlings.

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Figure 17. Comandra blister rust of hard pines (*Pinus* spp.) caused by *Cronartium comandrae*. A. Typical circular canker on older lodgepole pine, *Pinus contorta* var. *latifolia*. **B.** Main stem infection of young lodgepole pine. **C.** Close-up of telial horns on bastard toad-flax, *Comandra umbellata* var. *pallida*. **D.** Alternate states (mostly telia) on the underside of bastard toad-flax. **E.** A common alternate host, northern bastard toad-flax, *Geocaulon lividum*. **F.** Another common alternate host, bastard toad-flax.

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SWEET FERN BLISTER RUST OF HARD PINES

Cause

Sweet fern blister rust of hard pines (*Pinus* spp.) is caused by the rust fungus *Cronartium comptoniae* Arth.

Distribution and Hosts

Sweet fern blister rust is found across northern North America, from Nova Scotia to British Columbia and Alaska and south through New England to North Carolina. In Canada, major hosts of this rust are lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and jack pine (*P. banksiana* Lamb.). Other known hosts are shortleaf pine (*P. echinata* Mill.), mugo pine (*P. mugo* Turra), Bishop pine (*P. muricata* D. Don.), ponderosa pine (*P. ponderosa* Laws.), Monterey pine (*P. radiata* D. Don.), red pine (*P. resinosa* Ait.), and Scots pine (*P. sylvestris* L.). Two alternate hosts known in nature are sweet fern (*Comptonia peregrina* (L.) Coult.) and sweet gale (*Myrica gale* L.). Sweet fern is restricted to eastern North America. Sweet gale occurs across Canada, but in the prairie provinces it is limited to northern parts of the region, thus limiting distribution of this rust.

Symptoms and Signs

Symptoms and signs of this rust on pine stems are very similar to those of stalactiform blister rust (*Cronartium coleosporioides*), and identification of the two species has often been confused; however, longitudinal hypertrophied ridges produced by sweet fern blister rust (Fig. 18A) are not produced on stems infected by stalactiform blister rust. Some minor but distinct microscopical differences also exist between the two species.

Disease Cycle

Airborne basidiospores produced on the alternate hosts are responsible for infections on pine. Two to three years after infection, cankers and aecia containing powdery, yellow aeciospores develop. The windborne aeciospores produced on pine infect the leaves of alternate hosts (Fig. 18B) and develop uredinia in which urediniospores are produced that can reinfect alternate hosts. Later, columns of teliospores are produced, which germinate and release basidiospores.

Damage

This rust has caused significant damage in eastern North America in both young seedlings and larger trees, but because of the limited northern distribution of the rust, no significant economic loss has been observed in the prairie provinces. When reforestation activities and intensive management of hard pines increase in the northern region, this disease may become an important management consideration.

Control

Eradication of alternate hosts in and around high-value pine stands and timely application of a protective fungicide spray to nursery beds or ornamental trees are economically feasible recommendations.

Selected References

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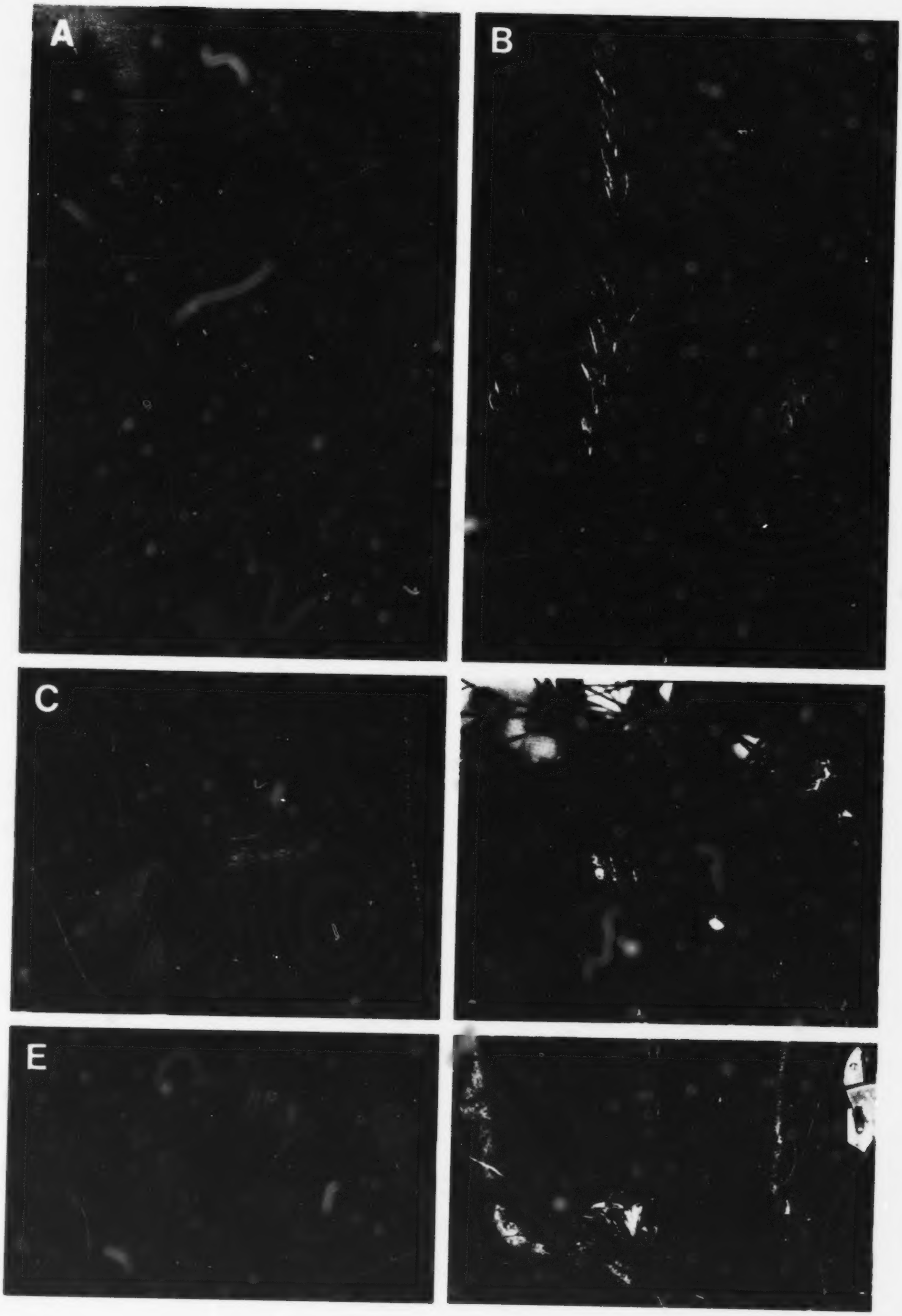
Ziller, W.G. 1974. The tree rusts of western Canada. Environ. Can., Can. For. Serv., Ottawa, Ont. Publ. 1329.

Figure 18. Sweet fern blister rust of hard pines (*Pinus* spp.) caused by *Cronartium comptoniae*. A. Infected jack pine, *Pinus banksiana*, with swollen ridges and blisters of aecia. **B.** An alternate host, sweet gale (*Myrica gale*).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WESTERN GALL RUST OF HARD PINES

Cause

Western gall rust of hard pines (*Pinus* spp.) is caused by the rust fungus *Endocronartium harknessii* (J.P. Moore) Y. Hiratsuka (≡ *Peridermium harknessii* J.P. Moore). Because the rust occurs across North America, several other names such as globose gall rust and pine-pine gall rust have also been proposed.

Distribution and Hosts

This rust is found across Canada, from Nova Scotia to the Yukon; in the east southward through New York, Pennsylvania, West Virginia, and Virginia; and in the west southward to Arizona and northern Mexico. It has often been confused with eastern gall rust (pine-oak gall rust, *Cronartium quercuum* (Berk.) Miy. ex Shirai), which also produces globose galls; however, *C. quercuum* is rare in Canada and probably does not exist in the prairie provinces. In Canada the major hosts of this rust are jack pine (*Pinus banksiana* Lamb.), lodgepole pine (*P. contorta* Dougl. var. *latifolia* Engelm.), and ponderosa pine (*P. ponderosa* Laws.), but it is also found on introduced pines such as mugo pine (*P. mugo* Turra), Bishop pine (*P. muricata* D. Don.), Austrian or Corsican pine (*P. nigra* Arnold), maritime pine (*P. pinaster* Ait.), Monterey pine (*P. radiata* D. Don.), and Scots pine (*P. sylvestris* L.).

Symptoms and Signs

Conspicuous perennial globose galls are produced on the stems of hard pines (Figs. 19A–F). During May to July powdery, orange-yellow spores are produced on the surface of galls. Very young galls are sometimes spindle-shaped rather than spherical (Fig. 19A) and can be confused with the spindle-shaped swellings produced by another pine stem rust, comandra blister rust (*C. comandrae* Pk.).

Disease Cycle

Unlike all other pine stem rusts in Canada, this rust has an autoecious cycle, i.e., it is capable of infecting pine directly without going to an alternate host. Spores produced on the galls (Fig. 19B) from the end of May to July become airborne and infect the green tissue of young shoots. Small galls appear a few months after infection but do not produce spores until the year following infection. Galls grow each year and produce spores every spring for many years, unless the gall tissue dies with the stem or sori are inactivated by mycoparasites.

Damage

Main stem galls often kill small trees, but small active galls usually increase annually in size and produce spores each spring for many years without killing the trees. Trees with main stem galls tend to be deformed and easy to break at the gall (Fig. 19C) and therefore are unsuitable for utilization. Branch galls on large trees do not affect the vigor of trees significantly. This disease tends to be intensified in highly managed young pine forests probably because of (1) the pine-to-pine life cycle, (2) the high susceptibility of vigorously growing shoots, and (3) the perennial nature of active galls, which serve as inoculum sources. A significant amount of western gall rust infection of nursery origin has been found in some plantations (Figs. 19A, F), pointing out the importance of producing disease-free planting stocks.

Control

One should avoid planting susceptible pine species near heavily infected stands. Young regenerated seedlings or planted seedlings with main stem galls should be removed. Eradication of galls during thinning operations may be effective in intensive management situations.

Timely protective fungicide applications are effective and economically feasible in tree nurseries or highly managed tree farms where high-value ornamental pines are grown. Eradication of infected trees or pruning of infected branches in and around tree nurseries should minimize the level of infection.

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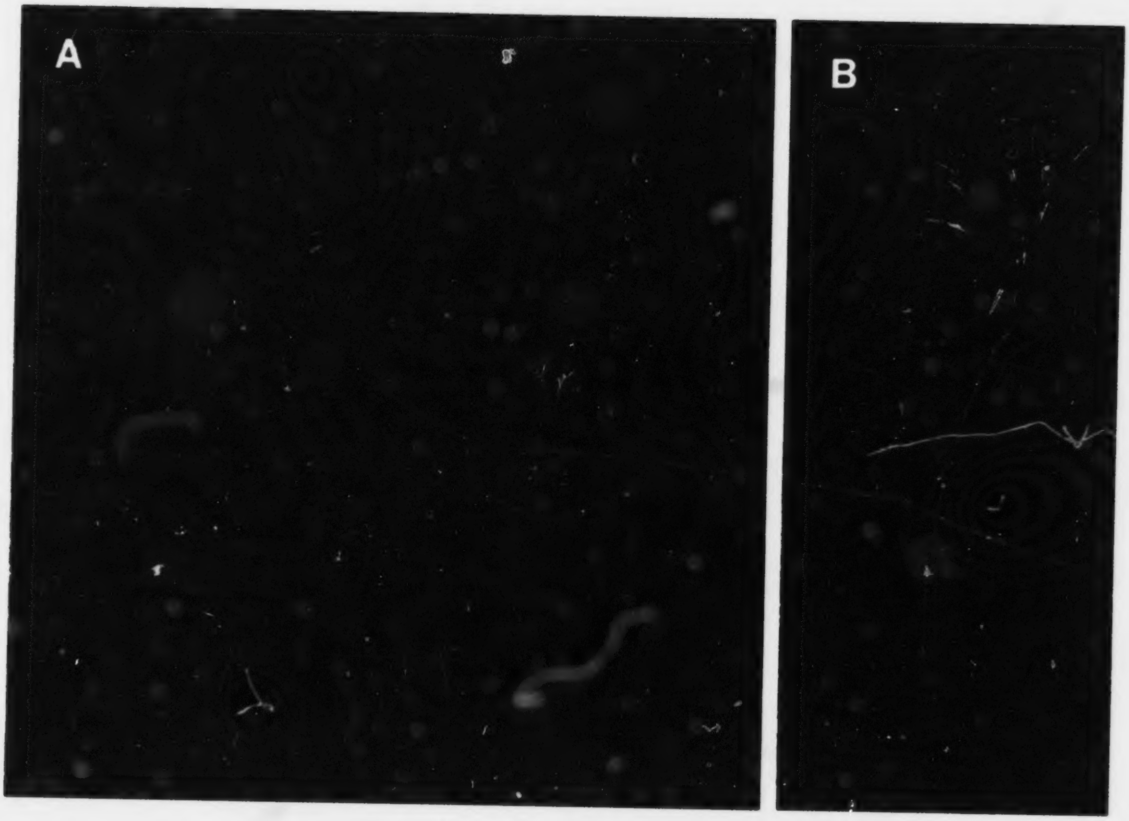
Figure 19. Western gall rust of hard pines (*Pinus* spp.) caused by *Endocronartium harknessii*. A. Nursery-infected seedlings of jack pine, *Pinus banksiana*. **B.** A sporulating gall and a new growing candle of lodgepole pine, *P. contorta* var. *latifolia*. **C.** A young lodgepole pine broken at the gall. **D.** Several galls on a lodgepole pine. **E.** Cross sections of galls. **F.** Basal gall formation in jack pines several years after planting, indicating nursery infections.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SCLERODERRIS CANKER

Cause

Scleroderris canker is caused by the fungus *Gremmeniella abietina* (Lager.) Morelet (= *Scleroderris lagerbergii* Gremmen), belonging to the class Ascomycetes.

Distribution and Hosts

Scleroderris canker is known widely in Europe, Asia, and North America. Many conifer species, including pines (*Pinus* spp.) (Figs. 20A, B), spruces (*Picea* spp.), Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), and larch (*Larix* spp.), have been recorded as hosts. In the prairie provinces this disease has been observed at a few locations in Jasper National Park on lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) (Fig. 20B), and it has been found on red pine (*P. resinosa* Ait.) in western Ontario close to the Manitoba border.

Two strains have been identified in North America. The North American strain is considered to attack young trees but causes only minor injuries to taller trees (more than 2 m). The second strain is found in New York and Vermont as well as limited locations in Quebec and the Maritime provinces. This strain has been known to kill large pole-sized Scots pine (*P. sylvestris* L.) and red pine in northern New York and Vermont. Strain distinction is not as clear as it was believed earlier.

Symptoms and Signs

Orange discoloration at the base of needles in the spring, dieback of branches, and green discoloration beneath the bark of dead branches are the typical symptoms of the disease (Fig. 20B). Conidia are formed in black sac-like pycnidia; they are falcate (new-moon-shaped) with pointed ends, four-celled, hyaline, 25–35 × 24 μm. Ascospores are produced in disk-like black fruiting structures (apothecia); they are ellipsoid, four-celled, hyaline, 15–20 × 4 μm.

Disease Cycle

Primary infection is by windborne ascospores produced in apothecia that appear on branches that have been dead for 1–2 years. Infections usually occur through buds or basal parts of needles into branchlets, and the fungus grows down to larger branches and then into the main stem of the tree. Major spore discharge and infection is in June and July. Asexual spores (conidia) ooze out of pycnidia during wet weather and are transported by rain splash to nearby branches, where they also cause infections. Pycnidia are usually produced at the base of dead needle fascicles as early as 2 months after the death of infected branchlets. Apothecia and pycnidia often occur together on dead branches.

Damage

This is an economically important disease of red pine in which initial infection appears when trees are small; however, this disease is not generally a serious factor in reforestation with lodgepole or jack pines.

Control

Eradication of infected trees from the stand can reduce infection and is economically justified in certain red pine plantations.

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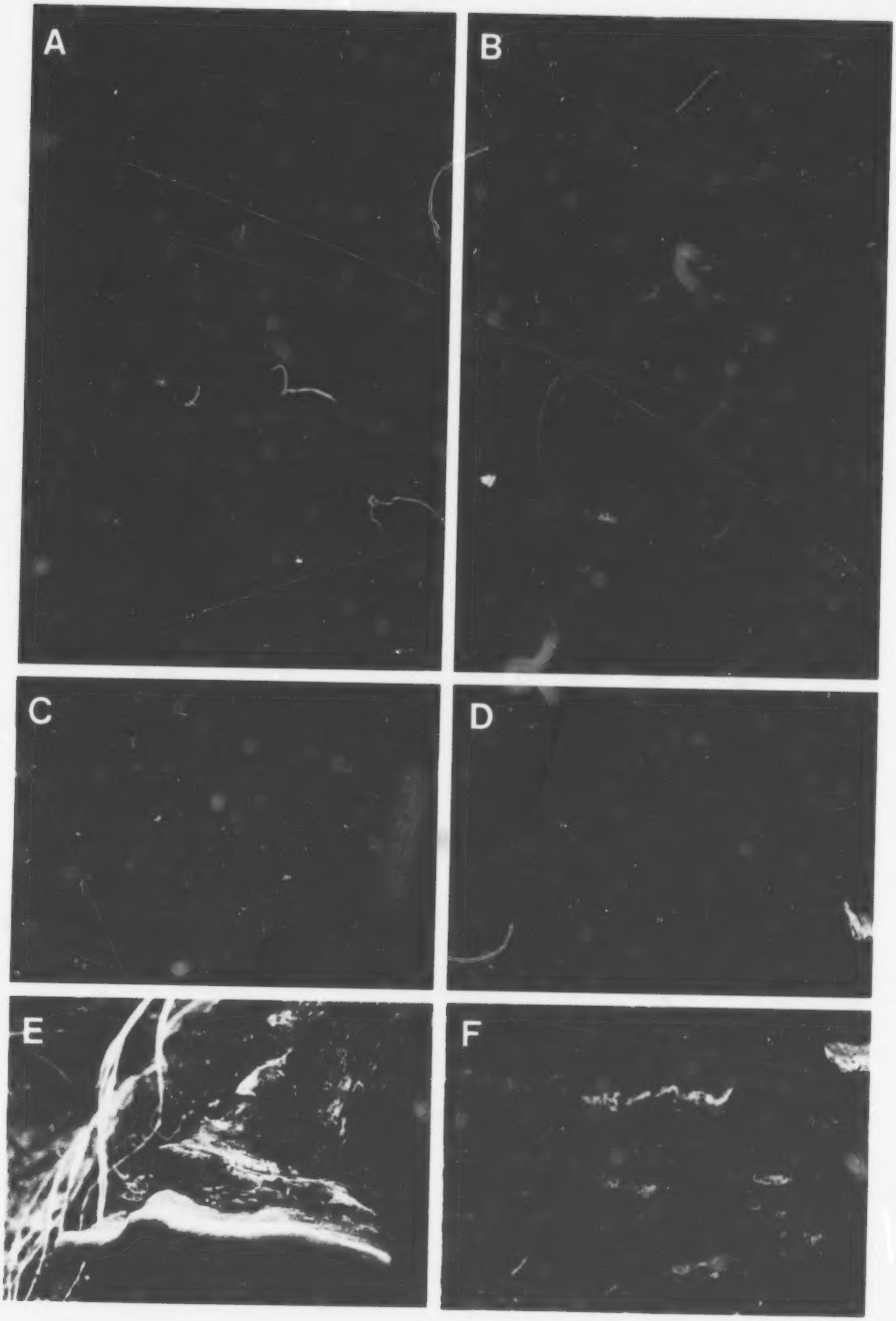
Figure 20. Scleroderris canker caused by *Gremmeniella abietina*. A. Nursery infection of jack pine, ***Pinus banksiana*. B.** An infected young lodgepole pine, *P. contorta* var. *latifolia*.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DECAY OF CONIFERS

Cause

Many fungi belonging to the class Basidiomycetes cause decay of the wood of roots, butts, and trunks of conifers. The 15 most common decay organisms associated with conifers in the prairie provinces are listed in Table 4 (p. 58-59). Red ring rot, *Phellinus pini* (Thore:Fr.) Pil. (≡ *Fomes pini* (Thore:Fr.) Lloyd.), is probably economically the most important decay fungus in the prairie provinces. Armillaria root rot is discussed separately (see Armillaria Root Rot).

Distribution and Hosts

All conifer species in the prairie provinces are attacked by various decay fungi (Figs. 21A-F), and a significant amount of decay is observed, especially when trees are mature or overmature.

Symptoms and Signs

Identification of decay fungi is based on characteristics of decay and morphology of fruiting bodies (often known as conks, mushrooms, etc.) associated with the decay. When fruiting bodies are not available, cultural and microscopical examinations of the fungus are necessary for positive identification.

Location of decay (heartwood, sapwood, root, butt, or trunk), type of decay (white rot or brown rot), or pattern of decay (e.g., pocket rot (Fig. 22A), stringy rot (Fig. 22B), or cubical rot (Fig. 22C)) are different among the decay organisms (see Table 4). White rot fungi are generally capable of digesting both carbohydrates (mainly cellulose and hemicellulose) and lignin, while brown rot fungi cannot digest lignin and thus appear brown.

Disease Cycle

Airborne basidiospores produced by the fruiting bodies are the main agents of dissemination of decay fungi. Infections are initiated through branch stubs and various kinds of stem or branch wounds caused by animals, machines, and other mechanical means. Armillaria root rot (*Armillaria obscura* (Pers.) Herink) and Tomentosus root and butt rot (*Inonotus tomentosus* (Fr.) Gilbertson) can also spread through the forest soil or by root contacts.

Damage

Wood with advanced stages of decay cannot be used, and cull due to decay is the most important element to be considered in timber inventory and harvest planning in mature and overmature conifer stands. Trees with extensive root or butt decay have reduced physical strength and can be toppled or broken easily by high winds or the weight of snow. Armillaria root rot and Tomentosus root and butt rot are known to kill young and older trees and create stand openings. Damage caused by decay fungi generally increases with the age of trees. For example, the incidence of heart rot of Engelmann spruce (*Picea engelmannii* Parry) in Alberta is observed to be 0% at 60-100 years, 17% at 101-140 years, 30% at 141-180 years, 60% at 221-260 years, and 100% at 301-340 years.

Control

Decay of conifers in most instances should be considered a natural condition of mature and overmature stands. Consequently, no direct control measures are practical. The losses caused by decay can be minimized by certain stand management practices, however, including use of proper pruning techniques, avoidance of mechanical damage to main stems, and harvesting mature and overmature stands before the decay becomes significant. It is important to apply various decay prediction systems to adjust gross volume to net volume in forest inventory.

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Figure 21. Decay of conifers. A. A fruiting body of *Phellinus pini*. **B.** Two fruiting bodies of *Inonotus tomentosus*. **C.** White pocket rot of heartwood caused by *Phellinus pini*. **D.** A fruiting body of *Echinodontium tinctorium*. **E.** A fruiting body of *Fomitopsis pinicola*. **F.** Small, thin, shelving fruiting bodies of *Hirshioporus abietinus*.

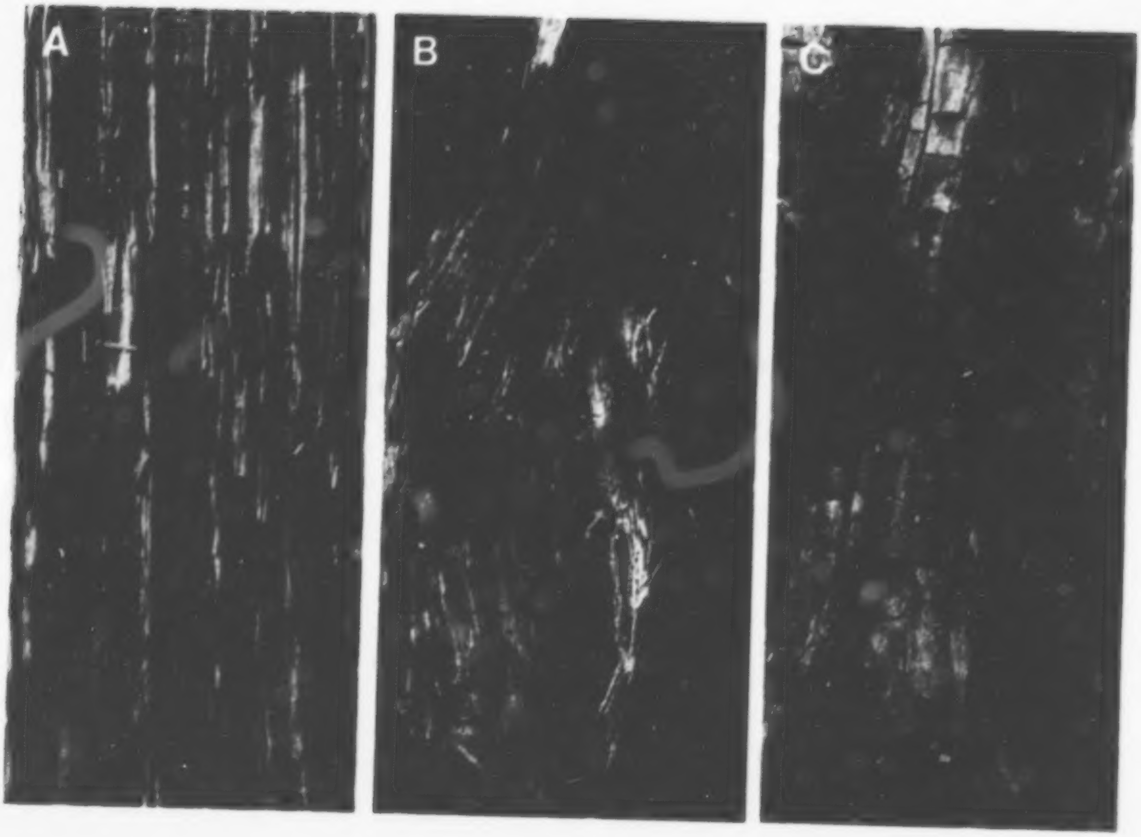
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Figure 22. Three typical types of decay. A. White pocket rot caused by *Phellinus pini* on white spruce, *Picea glauca*. **B.** Brown stringy rot caused by *Echinodontium tinctorium* on alpine fir, *Abies lasiocarpa*. **C.** Brown cubical rot of lodgepole pine, *Pinus contorta* var. *latifolia*, probably caused by *Coniophora puteana*.

Table 4. Descriptions of common decay fungi of coniferous trees in the prairie provinces

Organism	Type of decay	Fruiting body
Anisomyces odoratus (Wulf.:Fr.) Pat. ≡ *Trametes odoratus* (Wulf.:Fr.) Fr.	Brown cubical pocket rot	Small annual shelving conks; upper surface velvety, reddish brown to gray; lower surface with tubes
Armillaria obscura (Pers.) Herink = *A. ostoyae* (Romag.) Herink **Shoestring root rot, honey mushroom** (See Armillaria Root Rot)	Yellow to white spongy root and butt rot with numerous black zone lines; surface of decay hollow and often with dark brown wall	Honey- to brown-colored gilled mushroom with a ring (annulus) on stem (Figs. 23A, F)
Coniophora puteana (Schum.:Fr.) Karst.	Brown cubical rot (Fig. 22C)	Resupinate, thick, fleshy; surface olive-brown, margin cream colored
Echinodontium tinctorium (Ell. & Ev.) Ell. & Ev. ≡ *Fomes tinctorium* Ell. & Ev. **Indian paint fungus**	Brown stringy heart rot, with red streaks (Fig. 22B)	Hoof-shaped; upper surface cracked and blackish; lower surface toothed; context brick red (Fig. 21D)
Fomitopsis officinalis (Vill.:Fr.) Bond. & Sing. ≡ *Fomes officinalis* (Vill.:Fr.) Newman **Quinine conk**	Dark brown cubical rot	Large conks up to 60 cm wide, hoof-shaped, whitish
Fomitopsis pinicola (Sw.:Fr.) Karst. ≡ *Fomes pinicola* Sw.:Fr. **Red belt fungus**	Crumbly brown cubical rot	Large, perennial, flat, hoof-shaped conks; margin often reddish brown; upper surface crusty, gray-black (Fig. 21E)
Gloeophyllum saepiarium (Wulf.:Fr.) Karst. ≡ *Lenzites saepiarium* (Wulf.:Fr.) Fr. **Slash conk**	Brown pocket sap rot	Small, annual, shelving conks; upper surface yellow to dark brown; thin gills
Haematostereum sanguinolentum (Alb. & Schw.:Fr.) Pouzar ≡ *Stereum sanguinolentum* Alb. & Schw.:Fr. **Bleeding fungus, bleeding stereum**	Red heart rot	Resupinate to effused-reflexed conks; upper surface hairy, buff to gray, smooth purplish gray hymenial surface; red fluid oozes out when wounded
Hirschioporus abietinus (Dicks.:Fr.) Donk ≡ *Polyporus abietinus* Dicks.:Fr. **Purple conk**	White pocket rot, pitted sap rot	Small, annual, thin, shelving to resupinate conks; gray upper surface with hairs; lower surface purplish (Fig. 21F)
Inonotus tomentosus (Fr.) Gilbertson ≡ *Polyporus tomentosus* Fr. **Tomentosus root and butt rot**	White pocket root and butt rot	Circular, stiped, hairy upper surface, yellow to rusty brown; tube layer whitish, up to 6 cm in diameter (Fig. 21B)
Peniophora pseudo-pini Weres. & S. Gibson	Pink to red stain along rays and heartwood	Small rosy-brown to brownish purple velvety crusts

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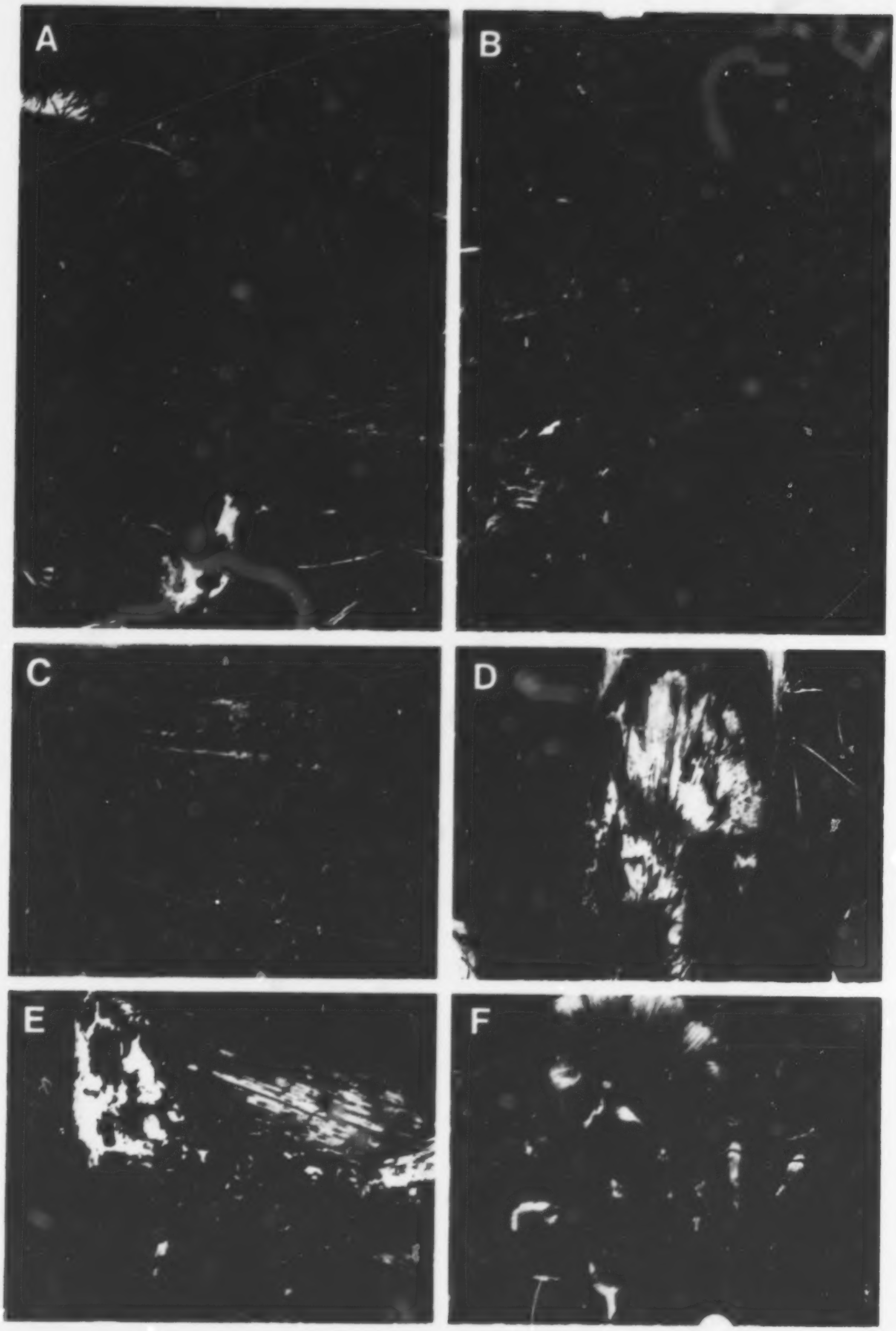
Table 4. Continued

Organism	Type of decay	Fruiting body
Phaeolus schweinitzii (Fr.) Pat. ≡ *Polyporus schweinitzii* Fr. **Velvet top fungus**	Brown cubical rot, red-brown butt rot	With or without central stalk; upper surface velvety, dark reddish brown; large angular pores
Phellinus pini (Thore:Fr.) Pil. ≡ *Fomes pini* (Thore:Fr.) Lloyd. **Red ring rot**	White pocket trunk rot; affected wood becomes reddish to purplish (Figs. 21C, 22A)	Shelving, 3-20 cm wide, variable shape; upper surface dark brown to black; furrowed underside yellow brown; brain-like irregular pores (Fig. 21A)
Pholiota alnicola (Fr.) Sing. ≡ *Flammula alnicola* (Fr.) Quél.	White rot	Stiped mushroom; surface and stipe scaly
Serpula himantioides (Fr.) Bond. ≡ *Merulius himantioides* Fr.	Brown cubical rot	Resupinate patches; hymenial surface irregularly folded, brown to raw umber; margin cream colored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ARMILLARIA ROOT ROT

Cause

Armillaria root rot is one of the most important diseases of young trees in natural regeneration and in plantations of conifers in the prairie provinces. The pathogen was previously considered a single species, *Armillaria mellea* (Vahl:Fr.) Kummer (≡ *Armillariella mellea* (Vahl:Fr.) Karst.), but recent studies indicate that the disease may be caused by many distinct species of *Armillaria*. The main species causing mortality of conifers in the prairie provinces is now confirmed to be *A. obscura* (Pers.) Herink (= *A. ostoyae* (Romag.) Herink).

Distribution and Hosts

This disease has been reported from most areas of the world and is common throughout the prairie provinces. Most species of coniferous and broadleaf trees have been known to be hosts. Common and economically important tree hosts in the prairie provinces are hard pines (lodgepole pine, *Pinus contorta* Dougl. var. *latifolia* Engelm.; jack pine, *P. banksiana* Lamb.; and red pine, *P. resinosa* Ait.) and spruces (white spruce, *Picea glauca* (Moench) Voss; Engelmann spruce, *P. engelmannii* Parry; and black spruce, *P. mariana* (Mill.) B.S.P.).

Symptoms and Signs

Some of the typical symptoms of Armillaria root rot are abrupt or gradual reduction in growth, bright reddish brown or yellowish discoloration of foliage over the whole tree (Figs. 23A–C), and resinosis around the root collar. White, radiating mycelial fans formed between the bark and wood around the base of infected trees are typical signs (Figs. 23D, E). Dark brown or black fungal strands called rhizomorphs or shoestrings are also formed on decayed wood or in the soil surrounding the diseased roots. In the fall, fruiting bodies (known as honey mushrooms) may be formed on diseased trees (Figs. 23A, F). The mushrooms are honey-yellow to brown, have annular rings (Fig. 23F), and are edible. In larger trees, the disease causes spongy root and butt rot with numerous fine, black zone lines.

Disease Cycle

The disease cycle of Armillaria root rot is not completely known. Infection of living trees probably occurs mainly by rhizomorphs and by root contacts or root grafts. Rhizomorphs are usually found on diseased tissue but are known to extend up to 10 m in the soil beyond infected host plants. Spores produced on sporophores (mushrooms), which disperse to dead stumps or other dead woody material, may also play some role in dissemination of the disease.

Damage

Small infected trees are usually killed quickly; large trees may have reduced growth but keep growing for a long time in spite of the presence of the fungus in the root system or as butt rot. Often it is difficult to assess the true impact of this disease because it tends to kill trees already weakened by unfavorable environmental conditions, insects, and other diseases. This disease is especially important in plantations or highly managed stands because it tends to kill young trees in groups and thus creates undesirable gaps in well-spaced stands.

Control

Direct control of this disease is not feasible or possible in most forest conditions, although stump removal to eliminate inoculum sources in second-generation stands is recommended. Following good silvicultural practices to ensure vigorous growth of trees and avoiding planting susceptible hosts on heavily infested sites will keep damage by this disease to a minimum. Use of relatively resistant tree species such as spruce, biological control by other fungi and mycophagous nematodes, and use of fungicides are being investigated for the possible control of this disease. Conifers established by seeding rather than planting of seedlings are also known to be less prone to the root rot.

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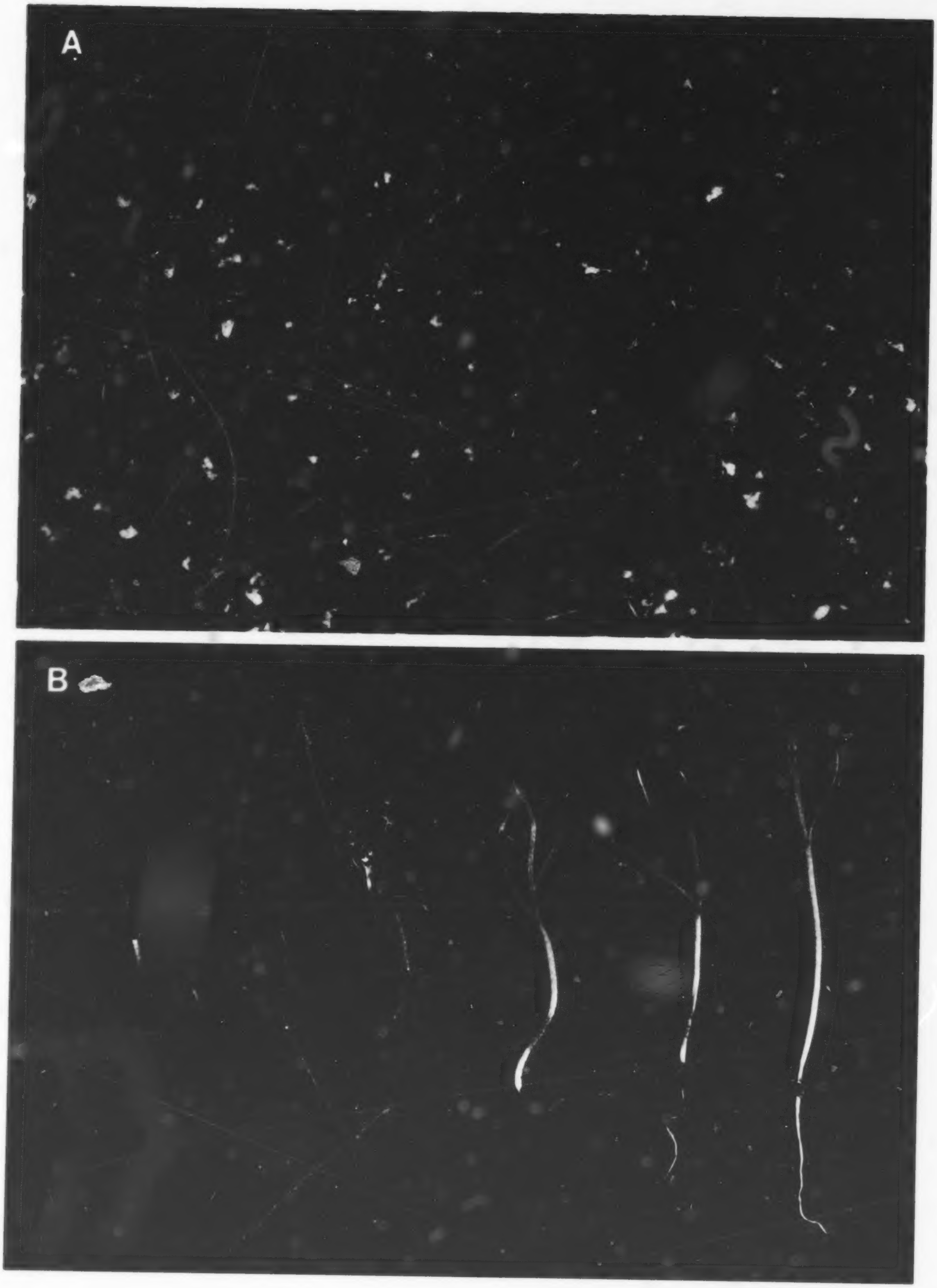
Figure 23. Armillaria root rot, *Armillaria obscura*. A. An infected lodgepole pine, *Pinus contorta* var. *latifolia*, with young mushrooms at the base. **B.** A dying lodgepole pine. **C.** An area near Hinton, Alberta, with significant mortality of regenerated lodgepole pine. **D.** White, fan-shaped mycelia at the base of an infected lodgepole pine. **E.** The root system of an infected tree showing extensive white mycelia under the bark. **F.** Mushrooms of various sizes.


A
B

DAMPING-OFF OF SEEDLINGS

Cause

Damping-off is a disease complex caused by a variety of soil-inhabiting fungi such as *Phytophthora* spp., *Fusarium* spp., *Pythium* spp., *Cylindrocladium* spp., and *Rhizoctonia solani* Kühn.

Distribution and Hosts

This disease complex occurs throughout the world wherever tree seedlings are grown in nurseries. All conifer and hardwood species are susceptible.

Symptoms and Signs

Only very young, succulent seedlings are susceptible; once the stems of seedlings begin to develop woody tissue, susceptibility declines rapidly. A necrotic or water-soaked area develops just below the groundline and weakens the stem, causing toppling of seedlings (Figs. 24A, B). Color of necrosis, presence or absence of visible mycelium, and speed of disease development are dependent on the fungus involved and environmental conditions present. In many situations more than one fungus may be involved.

If viable seeds die before germination or germinated seeds die before emergence, this is called preemergence damping-off.

Disease Cycle

Most of the fungi that can cause damping-off are native to nursery soil. Severity and extent of this disease are dependent more on the moisture, temperature, and nutrient status of the growing media than simply on the presence of one or more of the pathogenic fungi in the soil. Heavy, wet, alkaline soil favors the disease, and heavy fertilization may increase incidence of damping-off. Also, overcrowding of seedlings, high humidity, and poor air circulation or drainage favor damping-off.

Damage

Extensive damping-off of seedlings in nurseries is economically important. Populations of these pathogenic fungi tend to build up in nursery soils with each successive year of cropping, with average seedling losses increasing unless some control measures are implemented.

Control

Suitable growing media, well-aerated growing conditions, and proper moisture and temperature control should minimize the damage. Soil application of fungicides has been used to control damping-off in tree nurseries. Treatment of seeds with fungicides has also been used effectively for control of preemergence damping-off.

Selected References

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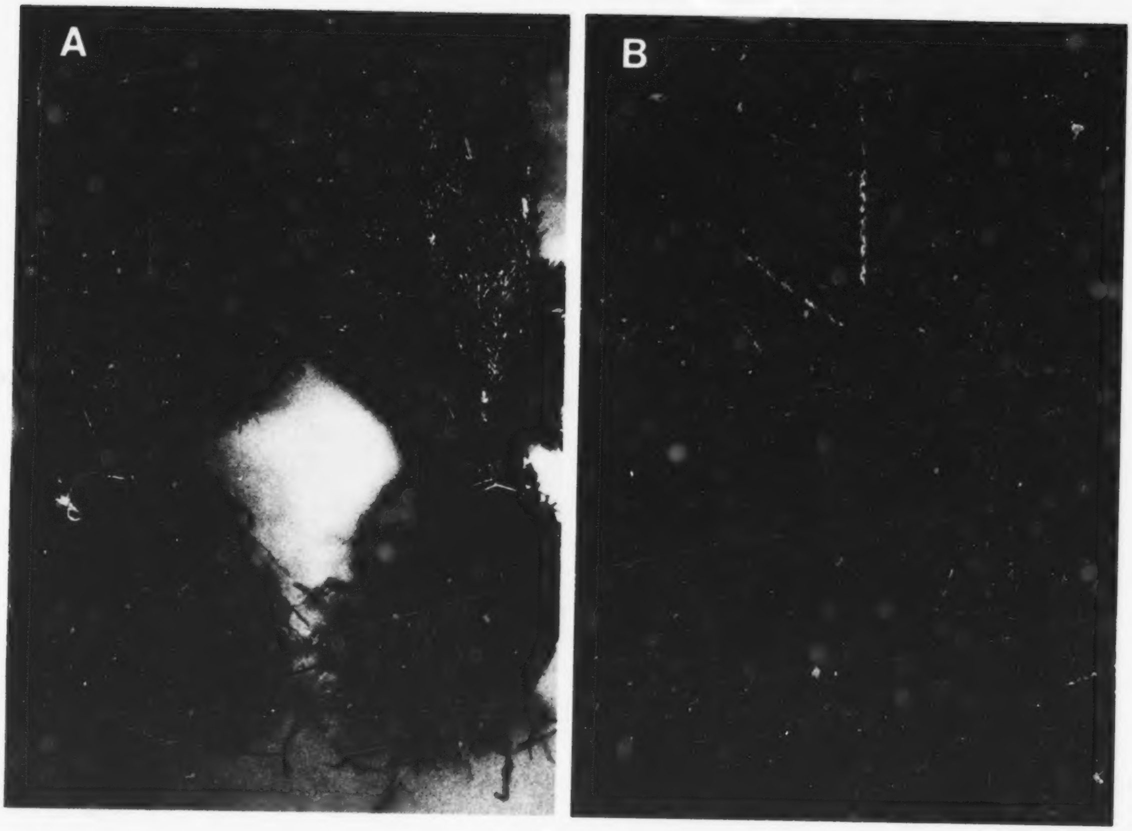
Figure 24. Damping-off of seedlings. A. Several affected seedlings of lodgepole pine, *Pinus contorta* var. *latifolia*. **B.** Close-up of damaged lodgepole pine seedlings showing various degrees of disease symptoms and a healthy seedling (far right).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STORAGE MOLDS OF CONIFER SEEDLINGS

Cause

Many kinds of fungi belonging to such genera as *Fusarium*, *Rhizopus*, *Aspergillus*, *Penicillium*, *Epicoccum*, *Rhizoctonia*, *Cylindrocarpon*, and *Botrytis* and many nonsporulating unidentified fungi are associated with the molding of stored seedlings. The most important cause of the storage mold problem, however, is the storage conditions rather than the presence of any specific fungus or group of fungi. High relative humidity, presence of free water, high storage temperature, and long storage period are known to encourage the storage molding problem. Very often the problem develops rapidly after the seedlings leave controlled nursery storage facilities if suitable temperature and humidity are not maintained during transportation or storage on site. The gray mold, *Botryotinia fuckeliana* is discussed in the next section (see Gray Mold of Stored Conifer Seedlings).

Distribution and Hosts

Although significant differences in susceptibility to storage mold damage are recognized among tree species, all species grown and stored in the prairie provinces are known to be affected.

Symptoms and Signs

Initial evidence of molding is the presence of cottony mold (hyphae) on the lower needles of the stored seedling bundles (Fig. 25A). Color and texture of fungal hyphae differ according to the species of fungus involved. They can be white, gray, orange, or various shades of brown. As the fungal growth covers the surface of seedlings, stem and needle tissues develop a water-soaked appearance and die (Fig. 25B). Affected needles often fall off. If the damage is not extensive, seedlings can be planted and the molding problem will usually disappear in the field.

Disease Cycle

Fungi that cause storage molding are common species present on seedlings, soil particles, dead organic debris, and containers or tools used in nursery operations; therefore, whenever suitable environmental conditions are present during storage of seedlings, molding will occur. Spores or mycelia in contact with free water on needles and stems grow and multiply if the temperature is favorable. Growth of the fungi tend to be superficial first but may result in the death of tissues. These fungi produce a large number of spores and mycelia and thus can spread quickly.

Damage

Death or damage caused by severe storage molding of conifer seedlings can be significant because it disrupts transportation and planting schedules.

Control

Storage mold of seedlings can be controlled by the choice of proper storage temperature, shortening of the storage period, and timely application of fungicides. Unfortunately, the frequently used fungicide Benomyl is known to increase the occurrence of fungus strains that are tolerant of it, thus limiting the effectiveness of control. Careful timing and attention to method of shipping and storage before planting are also important to minimize the damage. Although high humidity is generally considered to encourage molding, some reports indicate that water drip or spraying during the packing process is effective in preventing molding if the seedlings went into storage fully hydrated.

Selected References

Hocking, D. 1971. Effect and characteristics of pathogens on foliage and buds of cold stored white spruce and lodgepole pine seedlings. Can. J. For. Res. 1:208-215.

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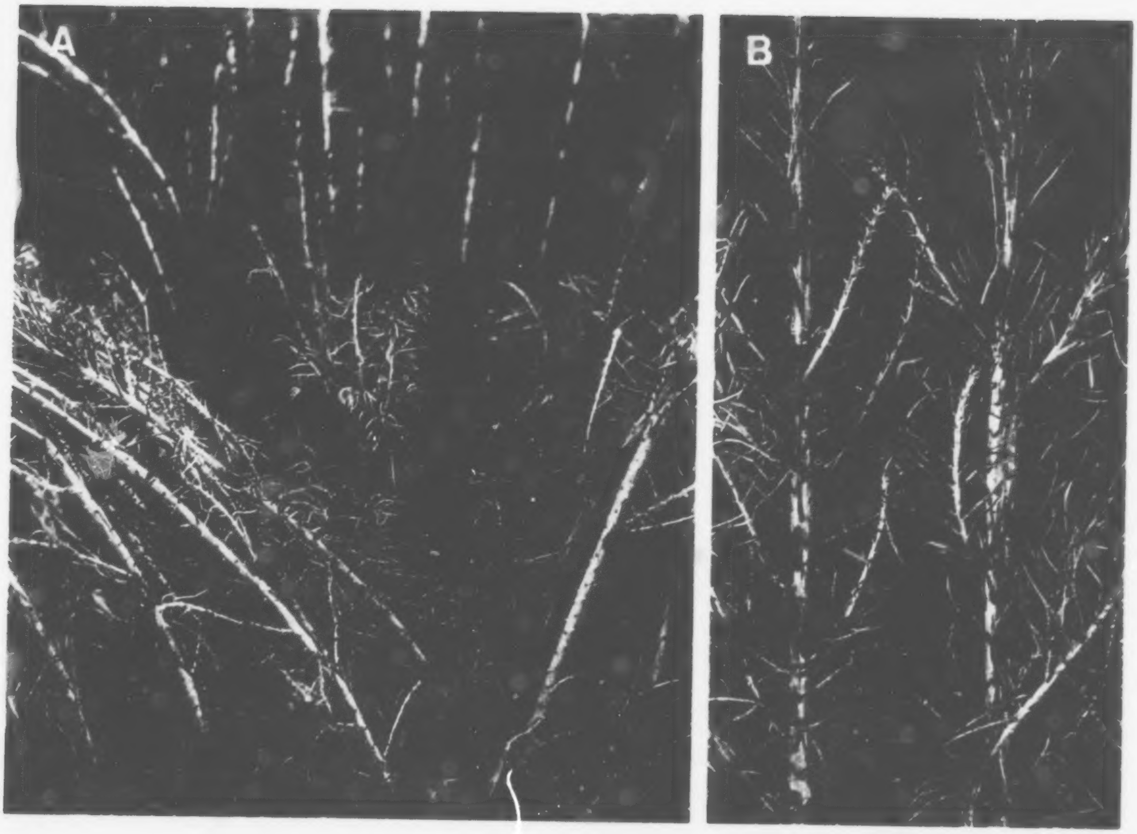
Figure 25. Storage molds of conifer seedlings. A. A heavily molded bundle of white spruce, *Picea glauca*, seedlings (right) and an unaffected bundle (left). **B.** An affected seedling of white spruce.


A
B

GRAY MOLD OF STORED CONIFER SEEDLINGS

Cause

Gray mold is caused by the fungus *Botryotinia fuckeliana* (d By.) Whetzel, belonging to the class Ascomycetes. The fungus has been known more widely by the name of its imperfect state (anamorph), *Botrytis cinerea* (Fr.) Pers.

Distribution and Hosts

The gray mold pathogen is one of the most ubiquitous fungi, with a very wide host range and worldwide distribution. Although the fungus probably lives mainly as a saprophyte on plant debris of all kinds, it causes economic loss of stored and transported fruits, vegetables, ornamental crops, and forest tree seedlings, especially those grown in containers.

Symptoms and Signs

Signs and symptoms of gray mold on containerized conifer seedlings include hyphal growth on the surface of plants, discoloration of needles, wilting, and development of brownish tan, water-soaked lesions (Figs. 26A, B). Gray-brown mycelia and characteristic small, whitish spore heads with single-celled spores on the surface of affected seedlings are the distinguishing characteristics.

Disease Cycle

Because this fungus is a common inhabitant of dead plant material, airborne spores (conidia) are abundantly available in most greenhouse or winter storage areas, especially when much dead plant debris is present under high humidity. The fungus can produce large numbers of conidia in a short time whenever proper moisture, temperature, and substrate are available.

Damage

Damage caused by this disease is becoming increasingly important as more conifer seedlings are grown and stored in containers under artificial environmental conditions. Gray mold damage can be significant, since it can affect all or a large part of a stored container-grown seedling. Usually the problem is identified shortly before shipment of seedlings, and consequently plans for transportation and field planting are upset. If the damage is limited to the bottom parts of seedlings and enough healthy shoots are still available, the gray mold condition may disappear once the seedlings are planted in the field.

Control

Fungicidal and cultural controls are used to minimize loss from this disease. Repeated use of one kind of fungicide in the same greenhouse or storage area is known to favor the occurence of fungicide-tolerant strains of the pathogen, especially with commonly used Benlate. Cultural controls are aimed at growing seedlings under conditions unfavorable to the pathogen, e.g., lowering humidity by less frequent watering or improved ventilation or reducing storage temperatures. Sanitation and removal of dead *Botrytis*-infested plant material from the storage area is important to reduce inoculum sources of the pathogen.

Selected References

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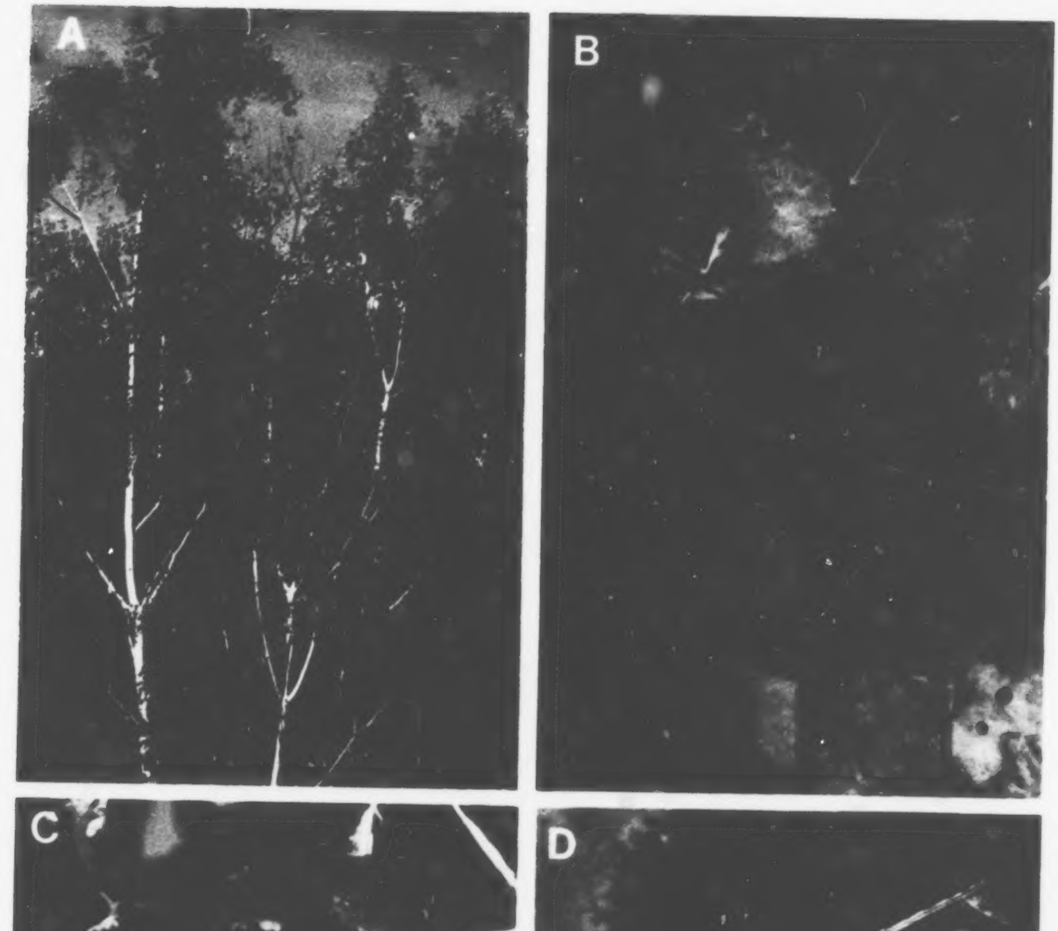
Figure 26. Gray mold of stored conifer seedlings, caused by *Botryotinia fuckeliana*. A. Gray mold damage on container-grown seedlings of white spruce, *Picea glauca*. **B.** Close-up of damaged white spruce seedlings.


A
B
C
D
E
F

LEAF SPOT DISEASES OF ASPEN AND POPLAR

Cause

Ten common or conspicuous leaf spot diseases of aspen and poplar (*Populus* spp.) are listed in Table 5 (p. 74). All belong to the class Ascomycetes, but some of them are found only as their anamorphs (imperfect states). Poplar leaf rusts and poplar leaf and shoot blight are discussed separately (see Leaf Rusts of Aspen and Poplar, and Aspen and Poplar Leaf and Twig Blight).

Distribution and Hosts

No detailed distribution data are available for each leaf spot disease in the prairie provinces. Main hosts for each disease are listed in Table 5.

Symptoms and Signs

There are some conspicuous symptoms for each leaf spot disease (Figs. 27A-F), but microscopic examination of spores (mostly conidia) is required for accurate diagnosis of most species. The characteristic symptoms and signs of each leaf spot disease are described in Table 5.

Disease Cycle

In general, airborne ascospores are produced on overwintered dead leaves in spring and initiate infections on newly formed leaves. Conidia can repeat infections during the growing season.

Damage

Infections are often heavy and cause premature shedding of leaves; however, leaf spot diseases seldom significantly affect the health of trees unless repeated severe infections occur.

Control

Protective sprays of selected fungicides may be effective and economically feasible in high-value ornamental or highly managed situations.

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Figure 27. Leaf spot diseases of aspen and poplar (*Populus* spp.). A, B. Ink spot, *Ciborinia whetzelii*, on aspen, *Populus tremuloides*. **A.** A heavily infected tree. **B.** Infected leaves with several dark round areas (pseudosclerotia). **C, D.** A leaf blight, *Linospora tetraspora*. **C.** An infected leaf of balsam poplar, *P. balsamifera*. **D.** Close-up of an infected leaf showing black fruiting bodies (ascostromata). **E.** Leaves of aspen infected with *Marssonina populi*. **F.** Black dot-like pycnidia of *Mycosphaerella populicola* on an aspen leaf.

Table 5. Common leaf spot diseases of aspen and poplar

Organism	Major hosts	Symptoms and conidia
Ciborinia whetzelii (Seaver) Seaver **Ink spot**	Aspen (*Populus tremuloides*)	Black, round sclerotia on discolored leaves drop during summer, leaving shot holes; no conidia (Figs. 27A, B)
Linospora tetraspora G.E. Thompson **Leaf blight**	Balsam poplar (*Populus balsamifera*)	Large brownish gray discolored areas, scattered black stroma on upper surface; no conidia (Figs. 27C, D)
Marssonina balsamiferae Y. Hirat. **Leaf spot**	Balsam poplar (*Populus balsamifera*)	Brown, angular spots on undersurface of leaves; conidia two-celled, 18–21 × 4.5–5.0 μm, tip cells pointed
Marssonina populi (Lib.) Magn. **Leaf spot**	Aspen, balsam poplar (*Populus tremuloides*, *P. balsamifera*)	Brownish round spots on upper side of leaves; conidia two-celled, unevenly divided, 19.0–23.5 × 6.5–8.0 μm (Fig. 27E)
Marssonina tremuloides Kleb. **Leaf spot**	Aspen (*Populus tremuloides*)	Brownish angular spots on underside of leaves; conidia two-celled, unevenly divided, 12–17 × 4–6 μm
Mycosphaerella populicola G.E. Thompson (anam. *Septoria populicola* Pk.) **Leaf spot**	Balsam poplar (*Populus balsamifera*)	Round leaf spots; sporulates on both sides of leaves; conidia two- to five-septate, 45–80 × 3.5–4.5 μm
Mycosphaerella populorum G.E. Thompson (anam. *Septoria musiva* Pk.) **Leaf spot**	Balsam poplar (*Populus balsamifera*) and hybrid poplars	Round leaf spots; sporulates on both sides of leaves; conidia one- to four-septate, 28–54 × 3.5–4.0 μm; also known to cause stem cankers (Fig. 27F)
Septogloeum rhopaloideum Dean & Bisby **Leaf spot**	Aspen (*Populus tremuloides*)	Large discolored areas, blister-like small pustules on underside of leaves; conidia usually three-celled, 40–50 × 8–12 μm
Venturia macularis (Fr.) E. Müller & Arx (anam. *Pollaccia radiosa* (Lib.) Bald & Cif.) **Leaf and twig blight** (See Aspen and Poplar Leaf and Twig Blight)	Aspen (*Populus tremuloides*)	Black shoot blight and leaf necrosis; conidia mostly two-celled, 18–26 × 5–8 μm
Venturia populina (Vuill.) Fabric. (anam. *Pollaccia elegans* Servazzi) **Leaf and twig blight** (See Aspen and Poplar Leaf and Twig Blight)	Balsam poplar (*Populus balsamifera*)	Black shoot blight and leaf necrosis; conidia mostly two-celled, 24.5–30.5 × 9–11 μm

A
B
C

ASPEN AND POPLAR LEAF AND TWIG BLIGHT

Cause

Two very similar leaf and twig blight diseases are caused by closely related fungal pathogens: *Venturia macularis* (Fr.) E. Müller (= *V. tremulae* Aderh., anamorph *Pollaccia radiosa* (Lib.) Bald. & Cif.) on aspen (*Populus tremuloides* Michx.) and *V. populina* (Vuill.) Fabric. (anamorph *Pollaccia elegans* Servazzi) on balsam poplar (*P. balsamifera* L.). They belong to the class Ascomycetes.

Distribution and Hosts

The two diseases are distributed widely throughout the prairie provinces and other parts of northern North America. *Venturia macularis* has also been observed on narrowleaf cottonwood (*P. angustifolia* James) and largetooth aspen (*P. grandidentata* Michx.). The main host of *V. populina* is balsam poplar, but black cottonwood (*P. trichocarpa* Torr. & Gray) is also known to be a host.

Symptoms and Signs

Blackening and wilting of young shoots and leaves are typical symptoms of the two diseases (Figs. 28A-C). Tips of the blackened shoots often bend back, producing the shepherd's crook symptom (Fig. 28B, C). On older leaves brownish black, irregularly shaped spots appear. Typical conidia are produced on infected leaves and young shoots and permit positive identification of the diseases (see Table 5, p. 74).

Disease Cycle

Ascospores and conidia produced on dead overwintered tissues are dispersed by wind and infect newly formed shoots and leaves in the spring. Conidia are produced on the blackened part of stems and leaves and reinfect young leaves. Once leaves develop fully and harden, no new infections seem to occur. Later in the fall and during the winter, the perfect stage of the fungi (perithecia with ascospores) begins to form on dead infected tissues.

Damage

When most of the tender shoots of young trees are attacked, the trees are disfigured and growth is severely affected. Infection on larger trees is rare and does not significantly affect their growth. It is suspected that these two diseases will become increasingly important when aspen and poplar are managed intensively in short rotations for pulp and lumber or for biomass for energy.

Control

No control measure is necessary at the present time for the two diseases.

Selected References

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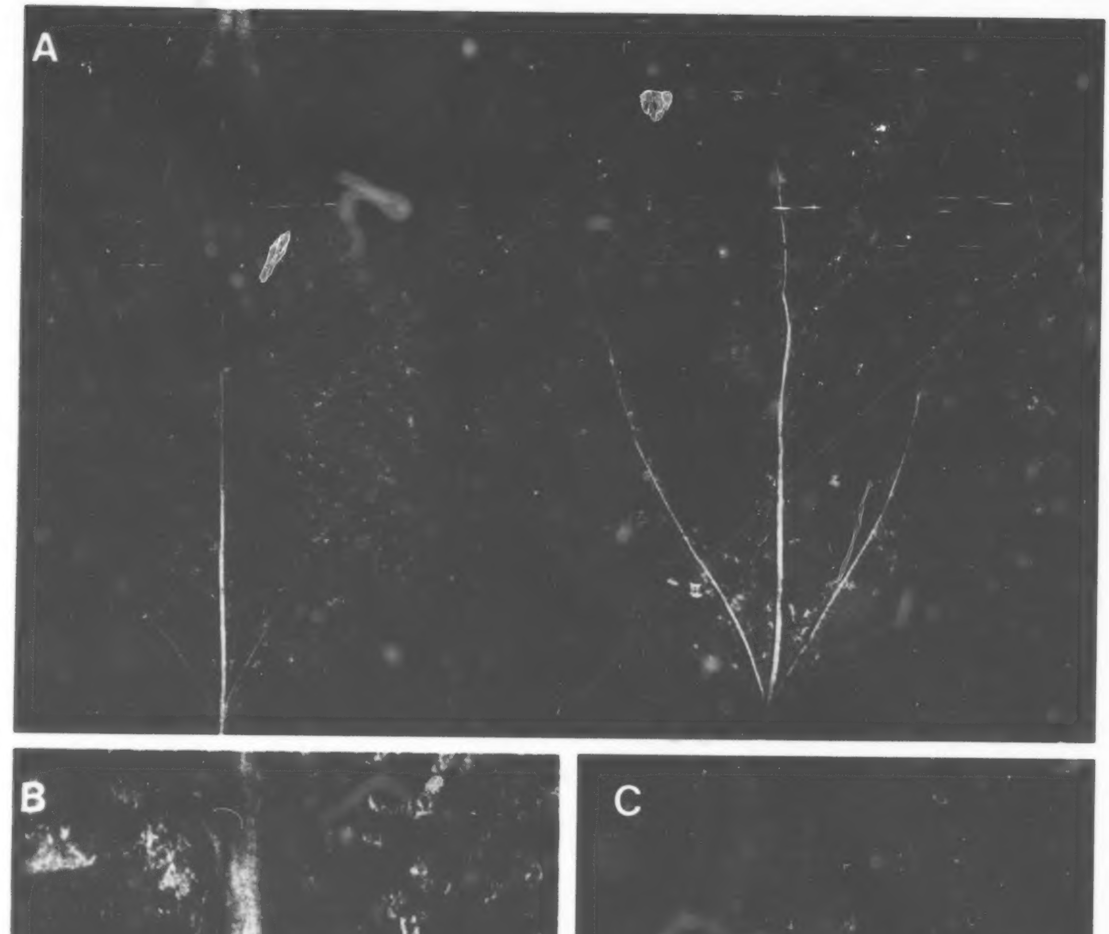
Dance, B.W. 1961. Leaf and shoot blight of poplars (section *Tacamahaca*) caused by *Venturia populina* (Vuill.) Fabric. Can. J. Bot. 39:875-890.

Figure 28. Aspen and poplar (*Populus* spp.) leaf and twig blight. A, B. *Venturia macularis* on aspen, *Populus tremuloides*. **A.** Infection on a young leaf. **B.** Shepherd's crook symptom on a young shoot. **C.** *Venturia populina* on balsam poplar, *P. balsamifera*, showing shepherd's crook symptom on a young shoot.


A
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D

LEAF RUSTS OF ASPEN AND POPLAR

Cause

Two species of rust are known on the leaves of aspen and poplar (*Populus* spp.) in the prairie provinces. They are *Melampsora medusae* Thuem. (= *M. albertensis* Arth.) (Figs. 29A, B) and *M. occidentalis* Jacks. (Figs. 29C, D).

Distribution and Hosts

Melampsora medusae is distributed throughout northern North America. In the prairie provinces this rust is mainly found on aspen (*Populus tremuloides* Michx.) but is also known on balsam poplar (*P. balsamifera* L.) and eastern cottonwood (*P. deltoides* Marsh.). Distribution of *M. occidentalis* is restricted to western North America and in the prairie provinces occurs in Alberta and Saskatchewan, commonly on balsam poplar, black cottonwood (*P. trichocarpa* Torr. & Gray), and hybrid poplars. Several species of larch (*Larix* spp.) are native alternate hosts of the two rusts in the prairie provinces, but other conifers such as Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), pines (*Pinus* spp.), and spruces (*Picea* spp.) are also known to serve as alternate hosts for these rusts elsewhere.

Symptoms and Signs

For both species the uredinial state appears on poplar hosts as powdery, golden-yellow pustules (Fig. 29B) on the underside of leaves and as yellow spots on the upper side of leaves. The two species can be distinguished by the size of urediniospores (15-23 × 23-35 µm for *M. medusae* and 16-29 × 32-45 µm for *M. occidentalis*). Later in the summer the telial state also appears among uredinia as smooth, raised, orange-yellow pustules (Fig. 29B). Telia turn from dark brown to black toward the end of the growing season (Fig. 29D). Heavily infected leaves are paler in color and tend to drop prematurely.

Disease Cycle

The powdery, yellowish orange spores, urediniospores, produced on poplars can reinfect poplar leaves and repeat several cycles of this state during the growing season, thus intensifying the infection. Later in the season, teliospores are produced on the leaves. Teliospores overwinter on dead fallen leaves and germinate in the spring to produce basidiospores, which infect coniferous alternate hosts on which they produce spermogonia and aecia. Aeciospores produced in aecia on the needles of conifers infect poplar leaves in early summer. There are strong indications that the two rusts can overwinter on poplar and start infection in the spring without going to an alternate host.

Damage

Because heavily infected leaves defoliate early, the general health of the trees can be affected; however, these rusts seldom kill infected trees. The damage becomes significant only in situations of intense cultivation and management or on poplar trees of ornamental value.

Control

No control measure is necessary for the leaf rusts of poplar at the present time in our region.

Selected References

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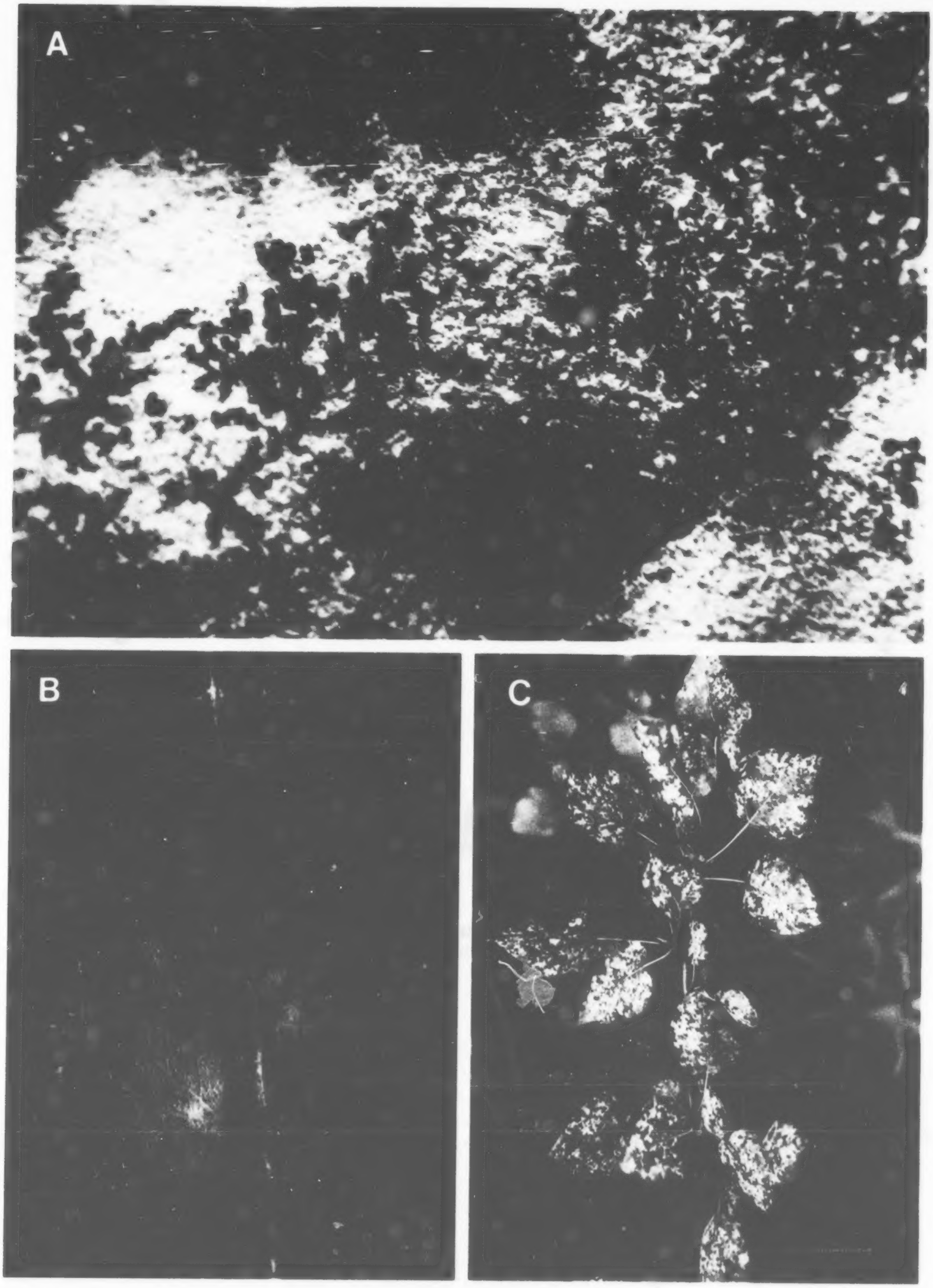
Figure 29. Leaf rusts of aspen and poplar (*Populus* spp.). A. Two leaves of aspen, *Populus tremuloides*, infected with *Melampsora medusae*. **B.** Close-up of *M. medusae* infection showing powdery, yellow uredinia and dark yellow to brown raised pustules of telia. **C.** *Melampsora occidentalis* on balsam poplar, *P. balsamifera*. **D.** Close-up of *M. occidentalis* showing pale brown to black telia.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POWDERY MILDEW OF BROADLEAF TREES

Cause

Four species of powdery mildew fungi are commonly found on various broadleaf trees in the prairie provinces. They are *Erysiphe aggregata* (Pk.) Farl., *Microsphaera penicillata* (Fr.) Lév., *Phyllactinia guttata* (Fr.) Lév., and *Uncinula salicis* (DC. ex Mérat) Wint. They belong to the order Erysiphales of the class Ascomycetes.

Distribution and Hosts

All four species have a wide host range, including many hardwood trees and herbaceous plants, and are distributed widely across the prairie provinces. Major tree hosts for each pathogen species are listed in Table 6. These fungi do not occur on conifers.

Symptoms and Signs

Powdery mildews are characterized by the presence of grayish white, powdery or dusty fungal growths on the surface of leaves and production of small brown to black spherical fruiting bodies (cleistothecia) (Figs. 30A–C). Heavily infected leaves may be discolored or disfigured, but light infection does not affect the appearance of leaves. Microscopic characteristics have to be examined to identify the species.

Disease Cycle

Powdery, white conidia are produced on the surface mycelia and can reinfect the host during the growing season. Dark spherical fruiting bodies (cleistothecia) (Fig. 30A), which are produced later in the growing season, overwinter on dead fallen leaves, and ascospores produced in them are released and infect newly formed leaves in the spring.

Damage

Powdery mildews do not kill their hosts; however, heavy infection can affect the general health and appearance of trees and thereby reduce their horticultural value.

Control

In general, the damage caused by powdery mildews is minor and it does not justify control measures. Fungicide sprays have been recommended for ornamental trees or nursery situations to reduce infection.

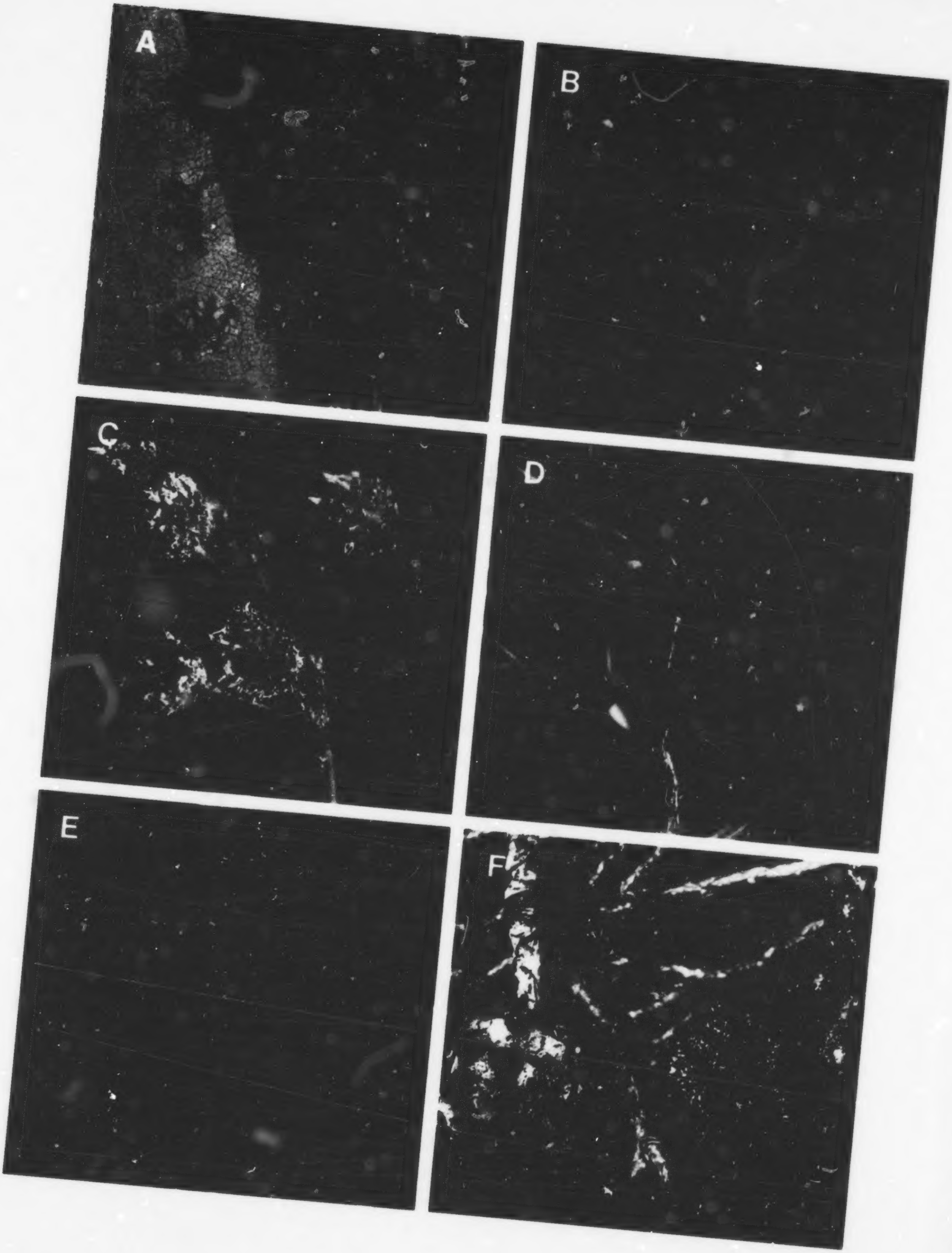
Selected Reference

Smith, C.G. 1971. Overwintering of cleistocarps of *Uncinula salicis* and *Microsphaera penicillata* in Alberta. Trans. Br. Mycol. Soc. 56:275–279.

Table 6. Powdery mildew species commonly found on broadleaf trees in the prairie provinces

Fungus	Hosts
Erysiphe aggregata (Pk.) Farl.	Alder (*Alnus* spp.)
Microsphaera penicillata (Fr.) Lév.	Alder (*Alnus* spp.), lilac (*Syringa vulgaris*), maple (*Acer* spp.)
Phyllactinia guttata (Fr.) Lév.	Alder (*Alnus* spp.), apple and crab apple (*Malus* spp.), cherry (*Prunus* spp.), mountain ash (*Sorbus* spp.), pear (*Pyrus* spp.), saskatoon (*Amelanchier alnifolia*), willow (*Salix* spp.)
Uncinula salicis (DC. ex Mérat) Wint.	Aspen and poplar (*Populus* spp.), willow (*Salix* spp.) (Figs. 30A–C)

Figure 30. ***Uncinula salicis*, a powdery mildew of aspen (*Populus* spp.) and willow (*Salix* spp.). A.** Close-up of infected leaf surface of aspen, *Populus tremuloides*, showing black (mature) and paler (immature) cleistothecia. **B.** An infected leaf of willow. **C.** Heavily infected aspen leaves.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LEAF AND BERRY RUSTS OF SASKATOON AND OTHER ROSACEOUS HOSTS

Cause

Four species of rust fungi belonging to the genus *Gymnosporangium* are known to attack saskatoon (*Amelanchier alnifolia* Nutt.) and other rosaceous hosts in the prairie provinces (see Table 7, p. 84).

Distribution and Hosts

The four species are widely distributed in all prairie provinces. *Gymnosporangium clavariiforme* (Pers.) DC. (Figs. 31A, B), *G. clavipes* Cke. & Pk. (Figs. 31C, D), and *G. nidus-avis* Thaxt. are known to parasitize many rosaceous hosts as well as saskatoon, but *G. nelsonii* Arth. (Figs. E, F) is apparently found only on saskatoon. Alternate hosts (telial hosts) of all four rusts include various species of juniper (*Juniperus* spp.) (Table 7).

Symptoms and Signs

Symptoms and signs distinguishing the four species are compared and listed in Table 7.

Disease Cycle

The basic life cycle of the four species is the same. Teliospores are produced on perennial infections of juniper. In the spring or early summer they germinate and produce basidiospores, which infect saskatoon (and other rosaceous hosts) and produce spermogonia and aecia. Aeciospores produced in aecia are responsible for infection on juniper. There is no uredinial stage in these rusts.

Damage

Of the four species, *G. clavipes* and *G. nelsonii* are the most common and cause significant economic damage, affecting small fruit production.

Control

Control is recommended only for ornamental and small fruit productions. Protective fungicide applications during basidiospore production or removal of junipers from the general area are considered feasible control actions.

Selected References

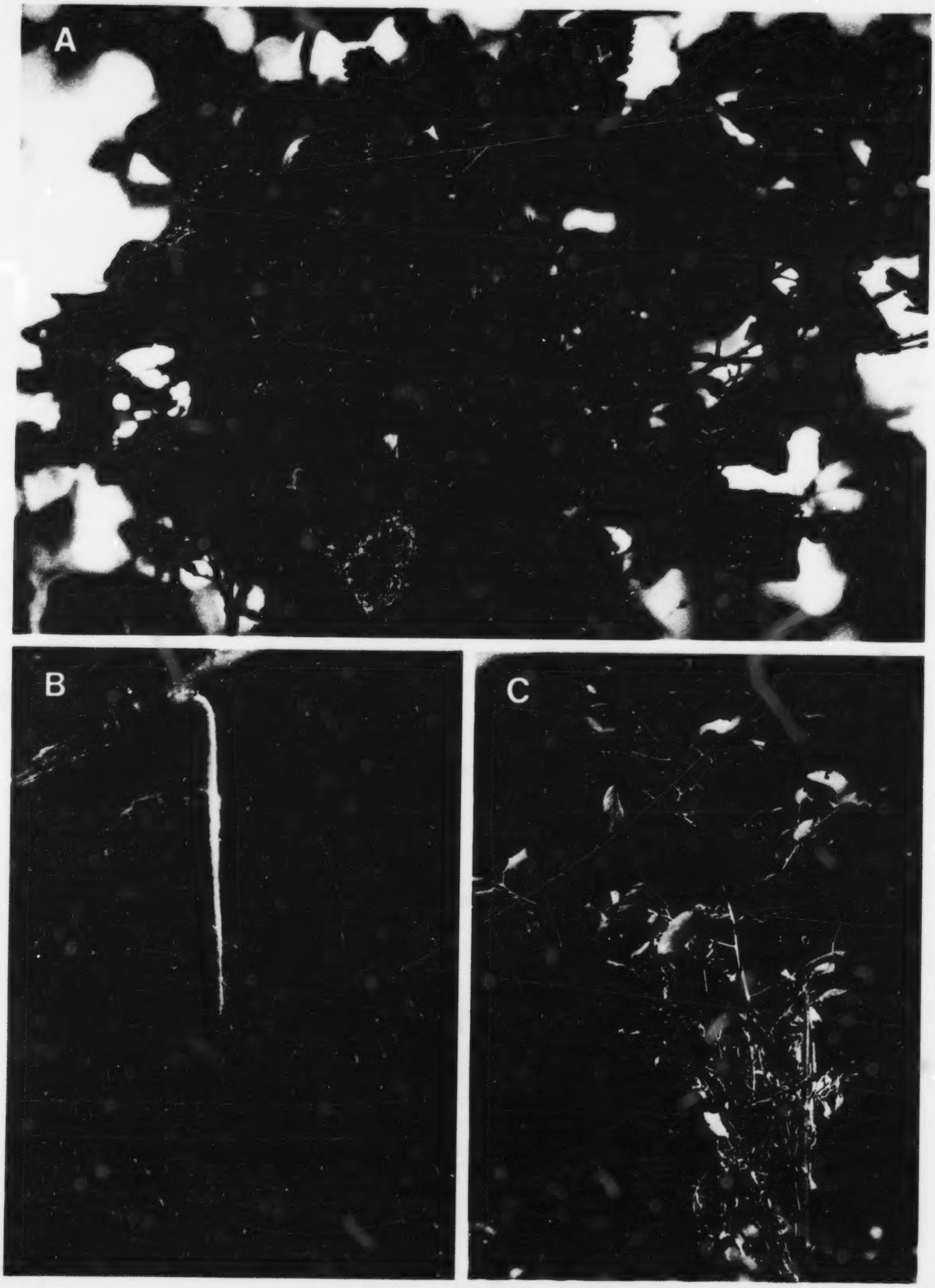
Parmelee, J.A. 1971. The genus *Gymnosporangium* in western Canada. Can. J. Bot. 49:903-926.

Ziller, W.G. 1974. The tree rusts of western Canada. Environ. Can., Can. For. Serv., Ottawa, Ont. Publ. 1329.

Figure 31. Leaf and berry rusts of saskatoon, *Amelanchier alnifolia*. A, B. *Gymnosporangium clavariiforme*. A. Leaf and fruit infections with aecia on saskatoon. B. Telial horns on common juniper, *Juniperus communis* var. *depressa*. C, D. *Gymnosporangium clavipes*. C. Infected fruits of saskatoon showing aecia. D. Raised reddish brown telia on a stem of common juniper. E, F. *Gymnosporangium nelsonii*. E. Leaf infections on saskatoon showing dark pointed aecia. F. Telial galls with gelatinous telial horns on creeping juniper, *J. horizontalis*. Unhydrated (left) and hydrated (right) galls.

Table 7. Symptoms, signs, and alternate hosts of the four species of *Gymnosporangium* that attack saskatoon in the prairie provinces

Species	Symptoms and signs	Telial hosts
Gymnosporangium clavariiforme (Pers.) DC.	Mostly on fruits and stems; aecia cup dehisces from the apex, cinnamon brown; aeciospores 23-36 (up to 41) × 21-32 μm; wall verrucose, yellow brown; germ pores 8-10 scattered (Fig. 31A)	*Juniperus communis* L. var. *depressa* Pursh, on fusiform swellings (Fig. 31B)
Gymnosporangium clavipes (Cke. & Pk.) Cke. & Pk.	Mostly on fruits but also stems; aecia cup shaped, orange yellow; aeciospores 28-46 × 22-38 μm, contents bright orange; wall colorless, densely verrucose; germ pores obscure, about 8 (Fig. 31C)	*Juniperus communis* var. *depressa*, on slight fusiform swellings (Fig. 31D)
Gymnosporangium nelsonii Arth.	Mostly on undersides of leaves but also on fruits; aecia dehisces both from apex and by lateral slits, chocolate brown; aeciospores 20-32 × 17.5-28.0 μm; wall yellow brown, densely verrucose; germ pores scattered, 6-10 (Fig. 31E)	*Juniperus horizontalis* Moench and *J. scopulorum* Sarg., on globose galls up to 2-3 cm (Fig. 31F)
Gymnosporangium nidus-avis Thaxt.	Mainly on underside of leaves but also on stems or fruits; aecia dehisced by lateral slits, brown; aeciospores 20.0-33.5 × 18.5-25.0 μm; wall dark yellow brown, densely verrucose; germ pores scattered, 8-10	*Juniperus horizontalis* and *J. scopulorum*, on needles, causing witches' brooms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BLACK LEAF AND WITCHES' BROOM OF SASKATOON

Cause

Black leaf and witches' broom of saskatoon (*Amelanchier alnifolia* Nutt.) is caused by the fungus *Apiosporina collinsii* (Schw.) Hoehn. (≡ *Dimerosporium collinsii* (Schw.) Thuem.) belonging to the class Ascomycetes. A closely related fungus, *A. morbosa* (Schw.) Arx, causes black knot disease of choke cherry and pin cherry (see Black Knot of Cherry).

Distribution and Hosts

This disease is distributed commonly throughout western North America on saskatoon but is known on several other species of *Amelanchier* in other regions.

Symptoms and Signs

Undersides of infected leaves are covered by an olive-brown to black fungal mat (Figs. 32A, B), which produces conidia and develops numerous black globose fruiting bodies (pseudothecia) that contain ascospores. Infected shoots produce witches' brooms (Fig. 32C), which enlarge each year. Dead blackened leaves remain on the brooms during the winter and can be spotted easily.

Disease Cycle

The fungus overwinters on dead, infected leaves and in the spring produces two kinds of infection spores (ascospores and conidia), which infect new shoots. Infections are systemic and perennial; therefore, new leaves produced on previously infected shoots are systemically infected.

Damage

The growth of heavily infected plants is greatly reduced, and the plants are aesthetically inferior. The ability to produce berries may also be reduced significantly.

Control

No control measure is practiced for this disease, but removal of infected stems is known to reduce the spread of the disease and improve the aesthetic value of infected trees. Branch pruning can be done effectively during the winter, since infected branches can be spotted easily.

Selected Reference

Kennedy, L.L.; Stewart, A.W. 1967. Development and taxonomy of *Apiosporina collinsii*. Can. J. Bot. 45:1597-1604.

Figure 32. Black leaf and witches' broom of saskatoon (*Amelanchier alnifolia*) caused by *Apiosporina collinsii*. A. An infected plant showing the black undersides of leaves. **B.** Close-up of the underside of an infected leaf. **C.** Witches' broom symptom of an infected plant.

A
B
C

SILVER LEAF

Cause

Silver leaf disease is caused by the fungus *Stereum purpureum* (Pers.:Fr.) Fr. (≡ *Chondrostereum purpureum* (Pers.:Fr.) Pouzar), belonging to the class Basidiomycetes.

Distribution and Hosts

Silver leaf disease occurs widely in the world, especially in urban and cultivated conditions. The causal organism has a wide host range. Major tree hosts in the prairie provinces are mountain ash (*Sorbus* spp.), apple (*Malus pumila* Mill.), hawthorn (*Crataegus* spp.), crab apple (*Malus coronaria* (L.) Mill.), pear (*Pyrus* spp.), plum (*Prunus* spp.), poplar (*Populus* spp.), willow (*Salix* spp.), cotoneaster (*Cotoneaster pyracantha* (L.) Spach), Nanking cherry (*Prunus tomentosa* Thunb.), and spruce (*Picea* spp.).

Symptoms and Signs

The first noticeable symptom is a silvering or leaden luster of the leaves (hence the name silver leaf), which is followed by browning of the leaf midribs and the leaf margins (Fig. 33A). Affected parts of the tree gradually lose vigor and eventually die (Fig. 33B). If the main stem is infected, the tree usually dies within 2-3 years. Small shelf-like fruiting bodies with a grayish white, hairy or velvety upper surface and purplish, smooth undersurface are produced at the bottom of affected trees (Fig. 33C). They are usually produced on pruning scars, branch stubs, or cracks on stems.

Disease Cycle

Basidiospores produced on the fruiting bodies infect open wounds or branch stubs and invade the sapwood, where the fungus causes decay. Although the fungus is usually confined to small areas around the initial infection, toxins produced by the organism affect the whole tree. Fruiting bodies are produced on standing trees but are also common on dead stumps and dead logs on the ground.

Damage

This is one of the most common and conspicuous diseases of ornamental and fruit trees in the prairie provinces and is most commonly seen on older, well-established trees. It causes a serious decay and reduces the value and yield of trees.

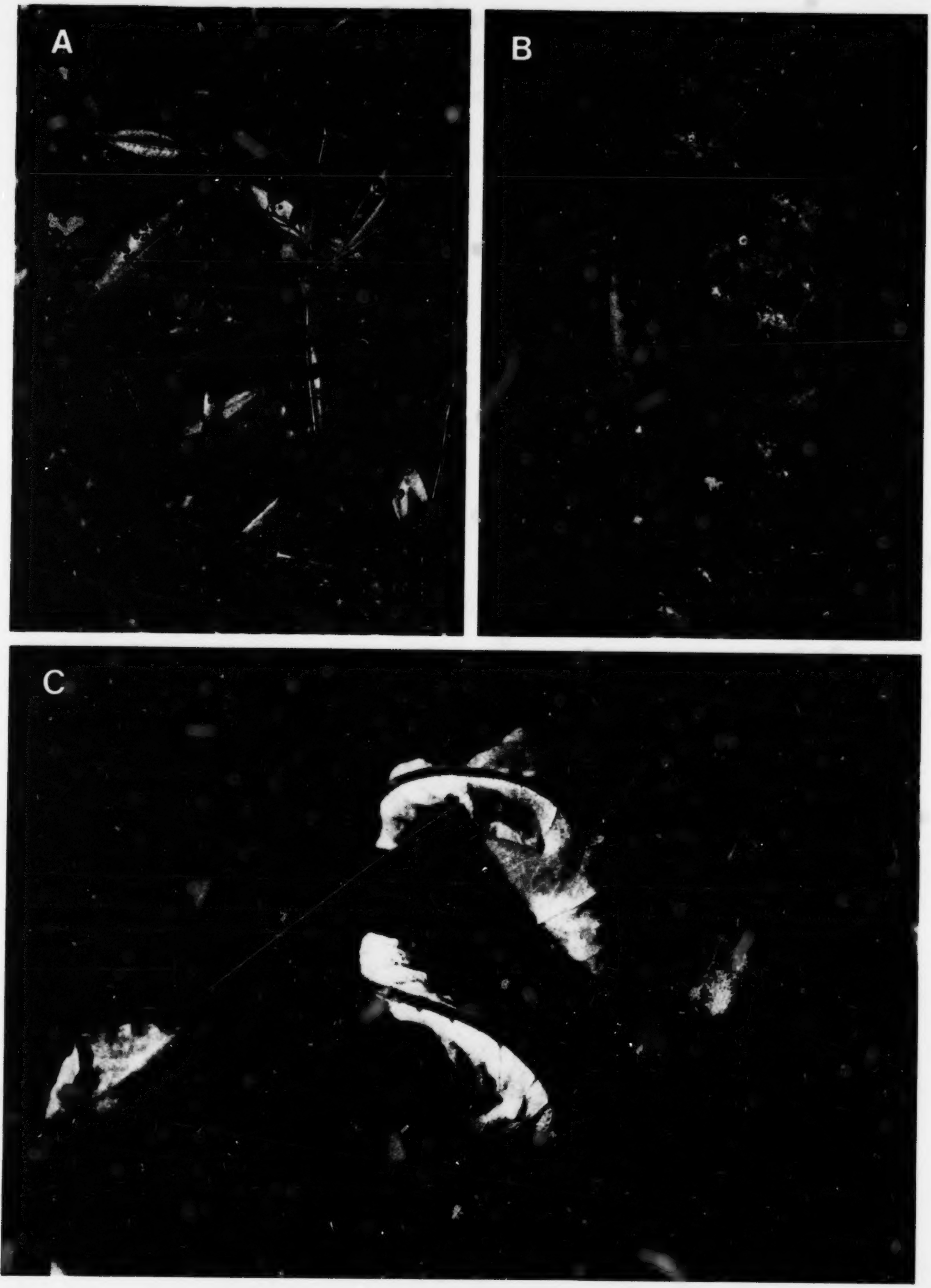
Control

There is no known chemical control measure for this disease, but protective fungicide applications immediately after pruning are considered effective in preventing infections in fruit orchards. Trees should be protected from mechanical injuries, and the proper pruning method should be used to reduce the chance of infection.

Selected Reference

Maruyama, P.J.; Hiratsuka, Y. 1985. Silver leaf. Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Pest Leafl. NFRC PL 26-85.

Figure 33. Silver leaf, *Stereum purpureum*. A. An affected branchlet (left) and a healthy one (right) of mountain ash, *Sorbus* spp. **B.** An infected mountain ash tree showing dieback and decline. **C.** Small shelf-like fruiting bodies with whitish hairy upper surface and smooth purple undersurface.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TAR SPOT AND BLACK VEIN OF WILLOW

Cause

Tar spot of willow (*Salix* spp.) is caused by *Rhytisma salicinum* (Pers.) Fr., and black vein is caused by *Ciborinia foliicola* (Cash & Davidson) Whetz. Both fungi belong to the class Ascomycetes.

Distribution and Hosts

The two diseases occur widely on various species of willow in the prairie region, but black vein is less known than tar spot, probably because it has a less conspicuous appearance.

Symptoms and Signs

The most conspicuous symptom of tar spot is the presence of circular, raised black mats of fungal tissue (stroma), 2-5 mm in diameter, scattered irregularly on the upper surface of leaves (Fig. 34A, B). Narrow yellowish bands of discoloration usually surround the stroma. Two kinds of spores are produced on the stroma. Ascospores are produced on grayish disks (apothecia) produced in the stroma and become exposed by fissures in the crust. Ascospores are filiform, hyaline, nonseptate, and 60-90 × 1.5-3.0 µm. Conidia (cylindric, hyaline, 5-6 µm long) are produced, usually before ascospores, in small dot-like fruiting structures (pycnidia) embedded in the stroma.

Black, raised ridges of fungal tissue (pseudosclerotia) along disfigured midribs of willow leaves (Fig. 34C) are the main diagnostic characteristic of the black vein disease. Small (up to 6 mm in diameter) cup-shaped apothecia with stalks are produced in overwintered pseudosclerotia on the ground. Ascospores are ellipsoid and nonseptate, mostly contain two conspicuous vacuoles, and are hyaline, 9-12 × 6-7 µm.

Disease Cycle

New infections of both tar spot and black rib of willow are initiated in the spring by ascospores produced on dead overwintered leaves on the ground. In the tar spot disease, conidia are likely to function as sexual spores (spermatia) and do not have the ability to initiate new infections.

Damage

Although the two diseases are conspicuous and infection is sometimes very heavy, they do not significantly affect the health of the host tree.

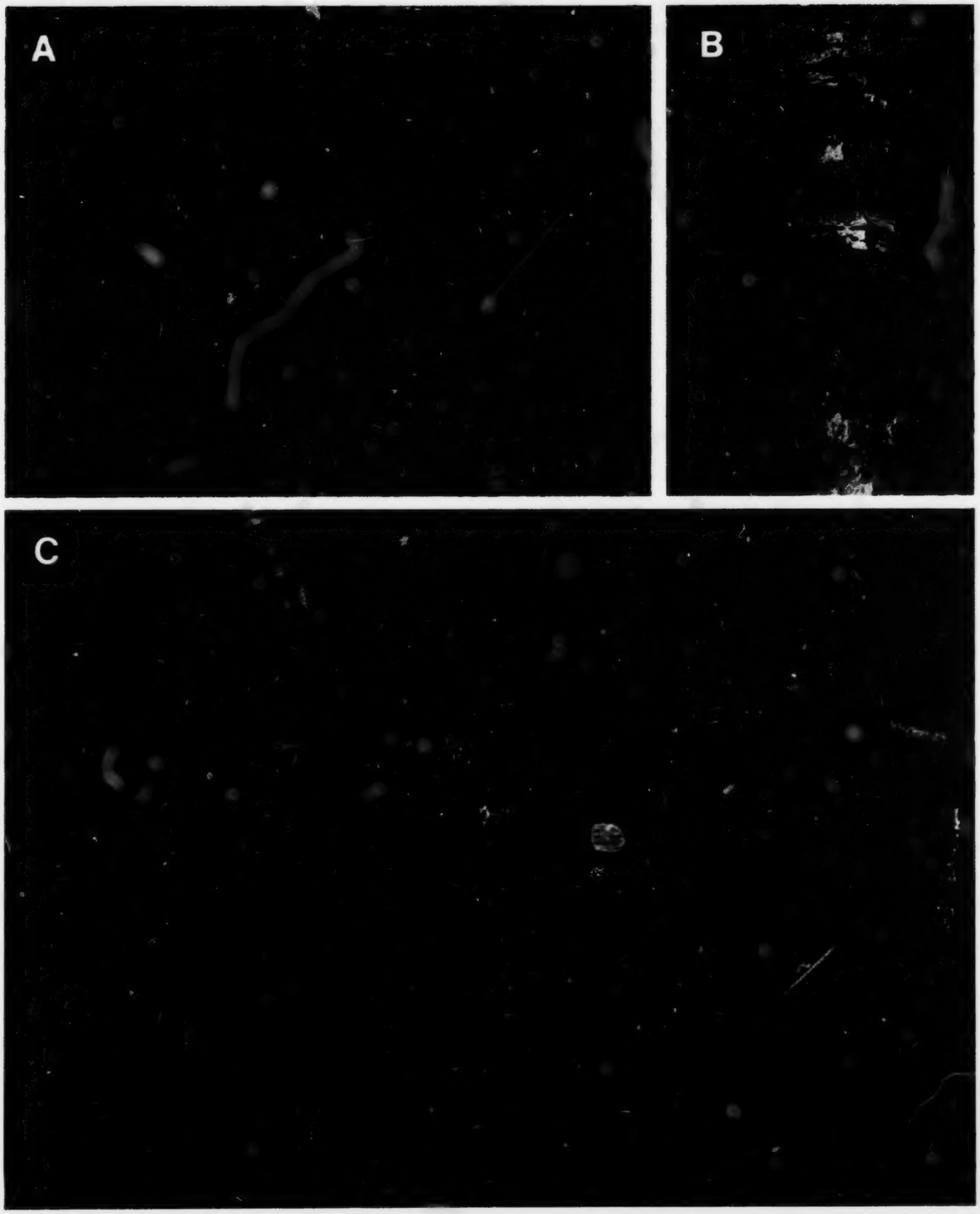
Control

No control measures are considered for these two diseases.

Selected Reference

Funk, A. 1985. Foliar fungi of western trees. Can. For. Serv., Pac. For. Res. Cent., Victoria, B.C. Inf. Rep. BC-X-265.

Figure 34. **Tar spot, *Rhytisma salicinum*, and black vein, *Ciborinia foliicola*, of willow, *Salix* spp. A. A willow plant heavily infected with tar spot. B. Close-up of an infected leaf showing black, raised pseudosclerotia. C. Curled leaves showing black vein symptom.**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DIPLODIA GALL AND ROUGH-BARK OF POPLAR

Cause

The cause of Diplodia gall and rough-bark of poplar (*Populus* spp.) is an ascomycetous fungus, *Diplodia tumefaciens* (Shear) Zalasky (≡ *Macrophoma tumefaciens* Shear, stat. holomorph. *Keisleriella emergens* (Karst.) Bose). Another fungus, *Rhytidiella moriformis* Zalasky, is also known to cause the rough-bark symptom on balsam poplar (*P. balsamifera* L.).

Distribution and Hosts

This disease is widely distributed throughout North America, and the major hosts in the prairie provinces are aspen (*Populus tremuloides* Michx.) and balsam poplar. This disease is also known on black cottonwood (*P. trichocarpa* Torr. & Gray), Lombardy poplar (*P. nigra* L. var. *italica* Muenchh.), Brooks poplar (*P. deltoides* Marsh. × Russian?), and other poplar hybrids and cultivars.

Symptoms and Signs

Globose branch galls of various sizes and the rough-bark symptom occur on trees of all ages (Figs. 35A–C). The bark of infected galls develops deep cracks, which result in the rough-bark appearance (Figs. 35B, C). Pycnidial fruiting bodies are often produced on the cracks. When infections occur on larger stems, the infected area consists of raised patches with the rough-bark symptom (Fig. 35B) and no globose galls.

Disease Cycle

Most of the infections are caused by conidia. An infection begins as a wart-like swelling on a young branch; the swellings grow as the stem increases in size and produce globose galls. On the other hand, an infection on a larger branch or stem results only in the rough-bark appearance.

Damage

This disease does not kill trees, but heavy infection does make ornamental trees unsightly and thus reduces their value.

Control

No chemical control measure is available at this time, but careful pruning of galls from heavily infected trees is recommended to minimize further spread of the disease.

Selected References

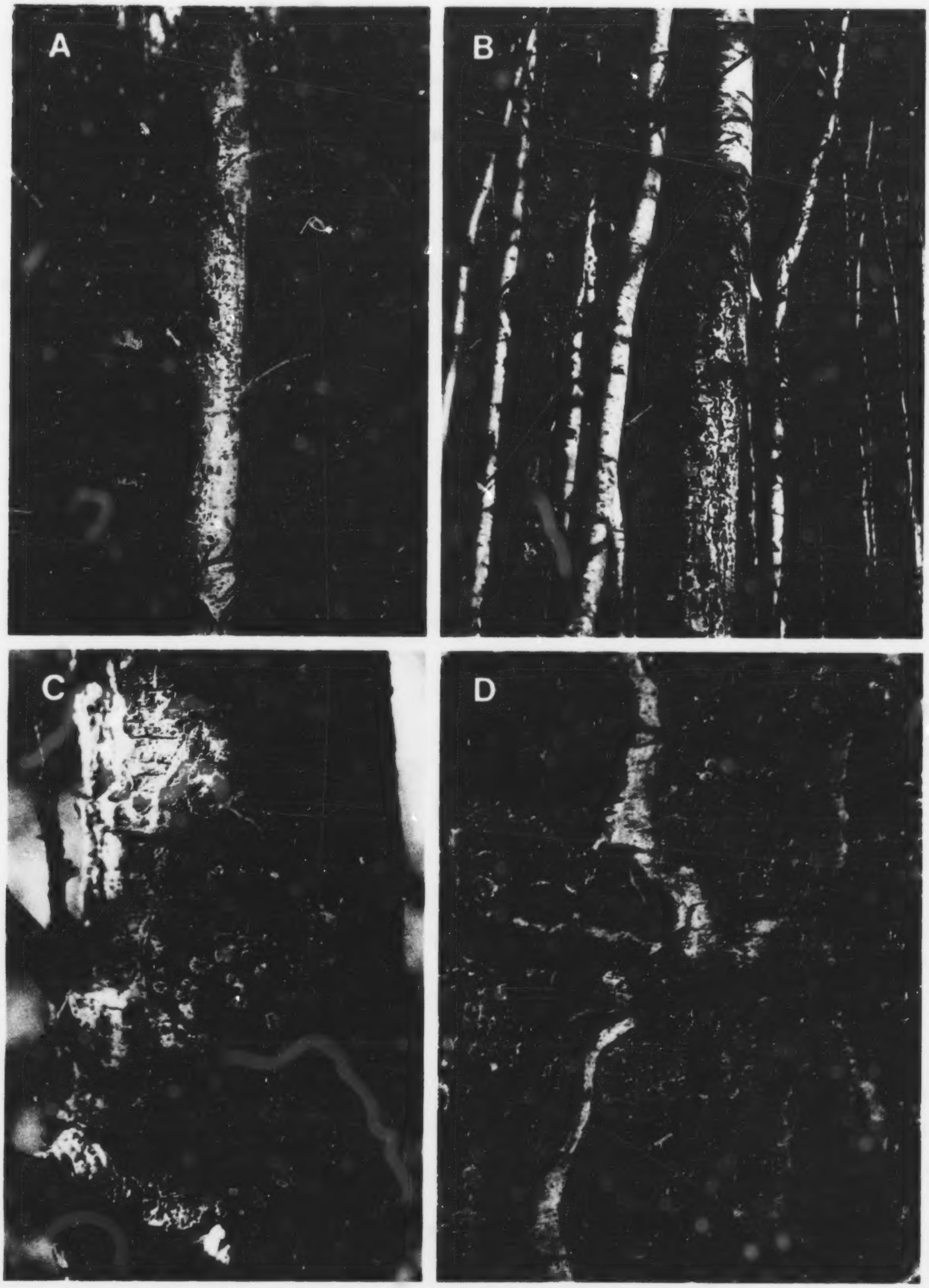
Zalasky, H. 1964. The histopathology of *Macrophoma tumefaciens* infections in black poplar. Can. J. Bot. 42:385–391.

Zalasky, H. 1964. Nomenclature and description of *Diplodia tumefaciens* (Shear) Zalasky (≡ *Macrophoma tumefaciens* Shear apud Hubert). Can. J. Bot. 42:1049–1055.

Zalasky, H. 1968. *Rhytidiella moriformis* n. gen., n. sp. causing rough-bark of *Populus balsamifera*. Can. J. Bot. 46:1383–1387.

Zalasky, H. 1970. Disease problems of poplar in the western interior of Canada. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. A-X-39.

Figure 35. Diplodia gall and rough-bark of poplar (*Populus* spp.) caused by *Diplodia tumefaciens*. A. An aspen, *Populus tremuloides*, heavily attacked by the disease. **B.** Rough-bark symptom on main stem of aspen. **C.** Close-up of young galls.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HYPOXYLON CANKER OF ASPEN

Cause

Hypoxylon canker of aspen (*Populus* spp.) is caused by the fungus *Hypoxylon mammatum* (Wahl.) J.H. Miller (= *H. pruinatum* (Klotzch) Cke.), belonging to the class Ascomycetes.

Distribution and Hosts

Hypoxylon canker is common throughout much of the range of trembling aspen (*Populus tremuloides* Michx.) in North America. The disease also occurs in largetooth aspen (*P. grandidentata* Michx.), balsam poplar (*P. balsamifera* L.), and a few other species of *Populus*.

Symptoms and Signs

The hypoxylon canker starts as a slightly sunken, yellowish orange area on the stem (Fig. 36A). The cankers enlarge rapidly and eventually girdle the stem (Fig. 36B). A mottled or laminated black and yellowish pattern of the cortex and a mycelial fan on the cambium layer are reliable field symptoms and signs of the disease. Older cankers are characterized by black hyphal pegs (Fig. 36C), which are pillar-like structures that push the outer periderm from the underlying cortical tissue. Hyphal pegs are imperfect fruiting structures that produce conidia. After a few years of infection, cankers produce fruiting bodies of the perfect state that are made up of 5-20 perithecia embedded in round stroma, 5-15 mm in diameter (Fig. 36D). The surface of the stroma is distinctly whitish at first but becomes black with age.

Disease Cycle

Dissemination of the pathogen takes place by ascospores, and they initiate infection. The role of conidia has not been established, but they may function as spermatia. How the infection starts on aspen is not clearly understood, but the fungus most likely gains entry through injuries on the stem or dead branch stubs. Insect and woodpecker transmission have been suggested but not yet confirmed. The pathogen can live as a saprophyte on dead wood and causes white rot; ascospores can be produced for several years after the death of the host trees.

Damage

Hypoxylon canker is considered to be one of the most important aspen diseases of the prairie provinces. This disease, however, is more common in poorly stocked aspen stands, trees under stress, or trees injured by hail, animal, or other means, indicating the secondary nature of the disease. Trees with infection on the lower main stem usually die within 5 years. Hypoxylon canker weakens the stem, which is often broken by wind at the point where the canker occurs.

Control

No practical control measures are known for Hypoxylon canker. Once the stand is heavily infected, the only practical recommendation is harvesting and replanting the site. Since different degrees of resistance to the disease have been recognized among various aspen clones, selecting and breeding may be feasible where more intensive cultivation of aspen is considered.

Selected References

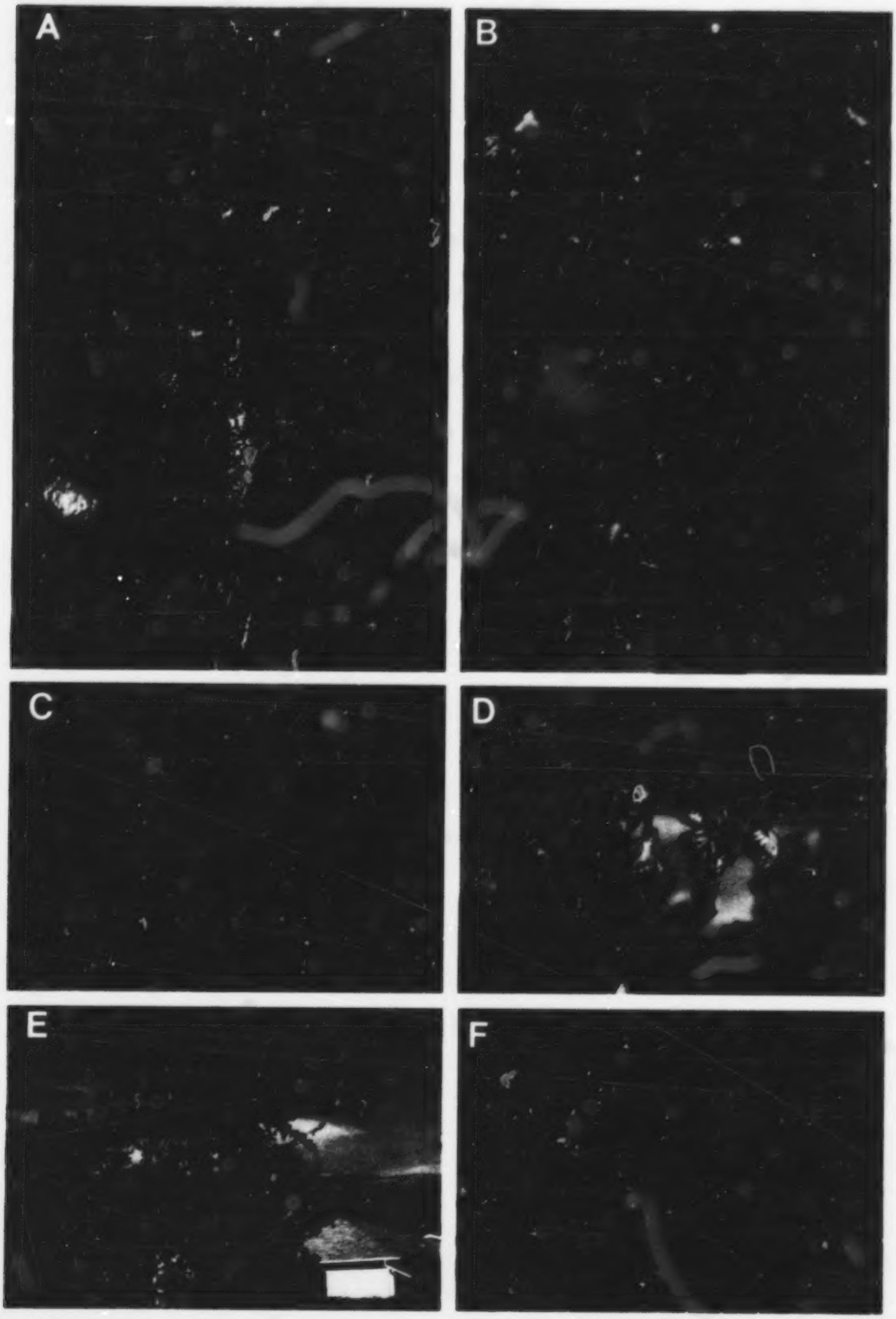
Anderson, R.L.; Anderson, G.W. 1969. Hypoxylon canker of aspen. U.S. Dep. Agric., For. Serv., Washington, D.C. For. Pest Leafl. 6.

Baranyay, J.A. 1967. Notes on Hypoxylon canker of aspen in Alberta. For. Chron. 43:372-380.

Hinds, T.E.; Krebill, R.G. 1975. Wounds and canker diseases on western aspen. U.S. Dep. Agric., For. Serv., Washington, D.C. For. Pest Leafl. 152.

Marion, P.D.; Griffin, D.H. 1986. Sixty-five years of research on Hypoxylon canker of aspen. Plant Dis. 70:803-808.

Figure 36. Hypoxylon canker of trembling aspen, *Populus tremuloides*, caused by *Hypoxylon mammatum*. A. A young canker showing yellow-orange bark discoloration. **B.** An advanced canker. **C.** Black hyphal pegs, which are the conidial state of the fungus. **D.** Several round stromatic fruiting structures made up of 10-20 perithecia.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FIRE BLIGHT

Cause

Fire blight is caused by a bacterium, *Erwinia amylovora* (Burr.) Winsl. et al. Another bacterial blight caused by *Pseudomonas syringae* Van Hall, which causes much less severe damage, also exists in the prairie provinces.

Distribution and Hosts

Fire blight is a native North American disease that occurs throughout North America, but it has been recognized in many locations in Europe in recent years. Hosts of fire blight are plants belonging to the family Rosaceae (rose family). Common hosts of the disease in the prairie provinces are apple (*Malus pumila* Mill.), crab apple (*Malus coronaria* (L.) Mill.), pear (*Pyrus* spp.), mountain ash (*Sorbus* spp.), cotoneaster (*Cotoneaster pyracantha* (L.) Spach), saskatoon (*Amelanchier alnifolia* Nutt.), hawthorn (*Crataegus* spp.), and raspberry (*Rubus* spp.).

Symptoms and Signs

Symptoms include blight of blossom, twig, leaf, collar, and root and cankers of branch and trunk (Figs. 37A, B). Milky viscous masses of bacteria often ooze out from the dark, water-soaked appearing cankers. Blossom blight is usually the first symptom of the disease. Blossoms first appear water-soaked and turn brownish to black as they wilt and shrivel (Fig. 37C). The disease spreads rapidly and invades supporting branches and neighboring leaves (Fig. 37D). Dead and shriveled blossom clusters together with infected fruitlet clusters usually remain attached to the tree and provide good diagnostic clues (Fig. 37C). Twig and leaf blight occurs on young succulent twigs and blackens and wilts them, often forming shepherd's crooks at their tips (Fig. 37D). When infection occurs on immature or mature fruits the bacteria spread rapidly and rot the fruits. In susceptible hosts the disease can advance into larger branches or even into main stems (Figs. 37E, F).

Disease Cycle

Fire blight bacteria overwinter in infected stem cankers. Bacteria also seem to be able to survive as surface organisms (epiphytes) and can contribute to initial infection in the spring. The bacteria are believed to be carried by wind, rain, and insects from winter cankers to blossoms or young tender shoots in the spring. Blossom infection then moves to the flower stem, the peduncle, and then into the leaves and branches. Secondary infections can occur when bacteria are disseminated by rain, wind, insects, and birds. Also, the disease is often disseminated by man on pruning equipment, transported fruits, or nursery stock.

Damage

This is probably the most important disease of ornamental rosaceous trees and shrubs in the prairie provinces. A severe infection can kill mature trees in one season, but some trees can survive for many years after infection.

Control

Once the infection occurs, no chemical can cure it. Pruning of diseased twigs and branches is the only effective method of control. Blossoms, the plant part most susceptible to infection, can be protected by spraying with antibiotics (streptomycin sulfate) or a fixed copper.

Selected References

Maruyama, P.J. 1978. Fire blight. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Pest Leafl. NFRC PL 23-78.

van der Zwet, T. 1979. Fire blight, a bacterial disease of rosaceous plants. U.S. Dep. Agric., Washington, D.C. Agric. Handb. 510.

Figure 37. Fire blight, *Erwinia amylovora*. A. A small canker on crab apple, *Malus coronaria*, probably caused by infection through a flower bud. **B.** A canker with a droplet of fire blight bacteria. **C.** A newly infected crab apple blossom bud showing wilting and discoloration symptoms. **D.** An infected young branch of crab apple showing the shepherd's crook symptom and discolored dead leaves. **E, F.** Heavily infected crab apple.

A
B

BLACK KNOT OF CHERRY

Cause

Black knot of cherry (*Prunus* spp.) is caused by the fungus *Apiosporina morbosa* (Schw.) Arx (≡*Dibotryon morbosum* (Schw.) Th. & Syd.), belonging to the class Ascomycetes. A closely related fungus, *A. collinsii* (Schw.) Hoehn., causes black leaf and witches' broom of saskatoon (*Amelanchier alnifolia* Nutt.) (see Black Leaf and Witches' Broom of Saskatoon).

Distribution and Hosts

This disease is distributed widely in North America. In Canada it is known from coast to coast. In the prairie provinces, choke cherry (*Prunus virginiana* L.) and pin cherry (*P. pensylvanica* L.f.) are the main hosts of the disease, but it is known on many other species of *Prunus* in other parts of North America.

Symptoms and Signs

Conspicuous greenish brown to black spindle-shaped swellings are the major symptom of the disease (Figs. 38A, B). Swellings or knots are usually confined to one side of the stem. The surface of the knot is covered by fungal stroma, in which the conidial state and perfect state develop. In the spring the knot surface is olive-green and has a velvety texture (Fig. 38B), but it turns black and smooth in the fall. Stem swellings are caused by hyperplasia (increased number) of xylem and phloem cells in the infected stems.

Disease Cycle

During April and May, ascospores produced in black, cushion-shaped overwintering ascostromata usually infect the youngest branches and occasionally the large older branches or trunks. Swellings increase in size each year, and spores are produced on their surface every year. The role of conidia is not clear, but they may also be involved in dissemination and infection.

Damage

Infected branches are deformed and growth is reduced significantly. Heavily infected trees often become stunted and deformed.

Control

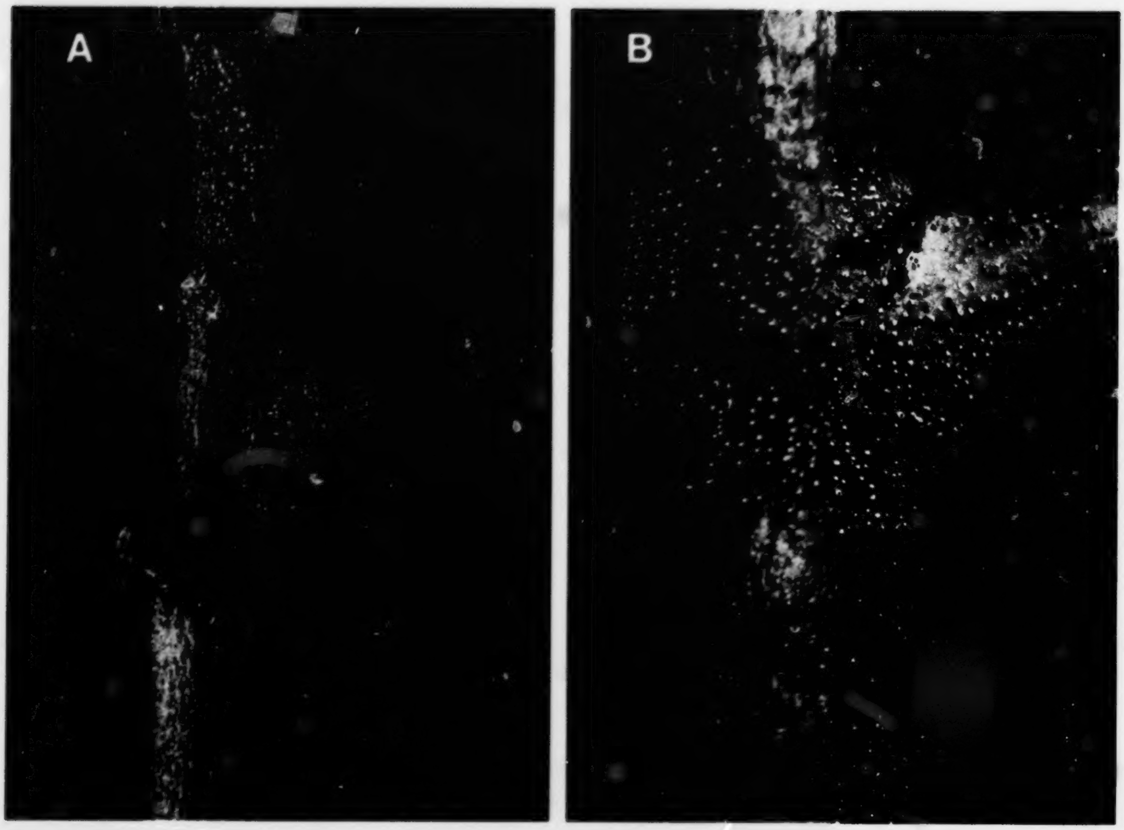
Pruning of infected branches at least 10 cm below the knots should eliminate the source of infection in the immediate vicinity.

Selected References

Corlett, M. 1976. *Apiosporina morbosa.* Fungi Can. 84.

Wysong, D.S.; Harrell, M.O. 1986. 32. Black knot of cherry and plum. Pages 70–71 *in* Forest nursery diseases in the United States. U.S. Dep. Agric., For. Serv., Washington, D.C. Agric. Handb. 470.

Figure 38. Black knot of cherry (*Prunus* spp.) caused by *Apiosporina morbosa*. A. A heavily infected choke cherry, *Prunus virginiana*. **B.** Close-up of an infected branch showing a black, spindle-shaped swelling.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NECTRIA AND CYTOSPORA ASSOCIATED WITH CANKER OF BROADLEAF TREES

Cause

Many textbooks and publications list fungi such as *Nectria* spp. and *Cytospora* spp. as canker-causing or dieback pathogens; however, they are likely colonizers of recently killed stem tissues rather than the primary causes of stem mortality. Common species of such fungi found in the prairie provinces are *Nectria cinnabarina* Tode ex Fr. (anamorph *Tubercularia vulgaris* Tode) and *Cytospora chrysosperma* (Pers.) Fr. (holomorph *Valsa sordida* Nits.). Another *Nectria* species, *N. galligena* Bres., is known to cause target canker on various deciduous tree species in eastern North America but does not occur in the prairie provinces.

Distribution and Hosts

The two species of fungi mentioned above are found across the prairie provinces on all common broadleaf tree species.

Symptoms and Signs

Nectria and *Cytospora* are found on dead branches or dead parts of stems. *Nectria cinnabarina* can be recognized easily by bright orange to pink raised pustules (sporodochia) (Fig. 39A). *Cytospora chrysosperma* can be recognized by black, multichambered pycnidia producing small, sausage-shaped hyaline spores (Fig. 39B). Thread-like masses of spores (tendrils) are often observed with *C. chrysosperma*.

Disease Cycle

Infections are known to be initiated by both conidia and ascospores, but the details of disease cycles of the two species are not known.

Damage

In certain situations the two fungi are very common and appear to be causing significant damage. Because their pathogenicity is doubtful, they should be considered secondary pathogens of dead or dying trees.

Control

Proper control or management strategies can be developed only when the biology of the pathogens, factors predisposing trees to infections, and nature of host-parasite relationships have been studied.

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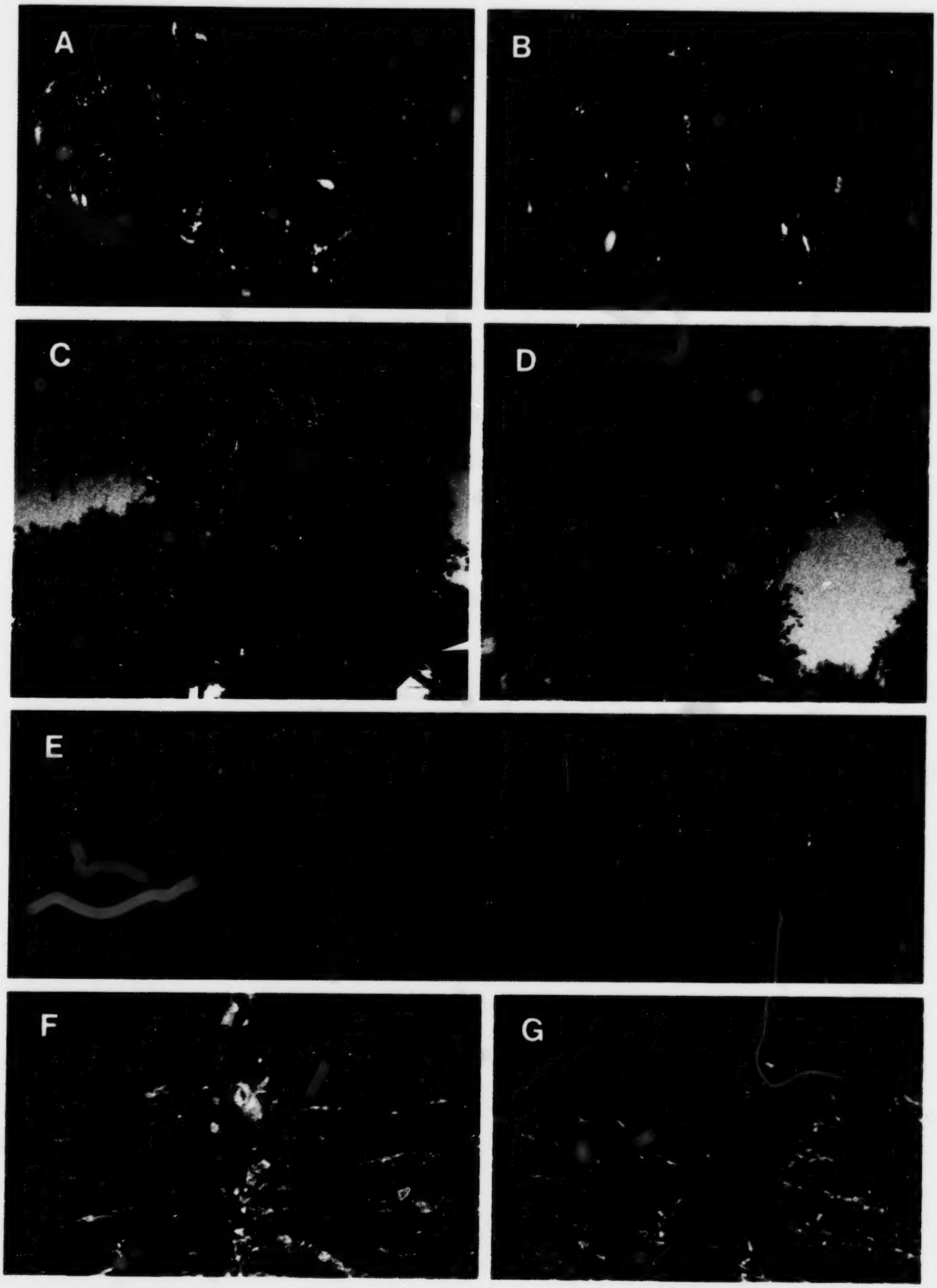
Spielman, L.J. 1985. A monograph of *Valsa* on hardwoods in North America. Can. J. Bot. 63:1355-1378.

Figure 39. *Nectria cinnabarina* and *Cytospora chrysosperma* associated with canker of broadleaf trees. **A.** *Nectria cinnabarina* on a cherry, *Prunus* spp. **B.** *Cytospora chrysosperma* on aspen, *Populus tremuloides*.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DUTCH ELM DISEASE

Cause

The pathogen of Dutch elm disease (DED) is *Ceratocystis ulmi* (Buis.) C. Moreau (≡ *Ophiostoma ulmi* (Buis.) Nannf., *Ceratostomella ulmi* Buis., anamorph *Pesotum ulmi* (Schw.) Crane & Schokrecht). Two other wilting diseases of elm (*Ulmus* spp.) caused by *Dothiorella ulmi* Verrall & May and *Verticillium albo-atrum* Reinke & Berth. are also associated with the same insect vectors, but they are considered to be much milder diseases than DED.

Distribution and Hosts

This disease is distributed widely in Europe and North America. The disease was found for the first time in the prairie provinces in Manitoba in 1975 and has been spreading steadily throughout southeastern Manitoba. In 1981 one tree in Regina was diagnosed as having DED, the first record of it in Saskatchewan. The disease has not so far been reported from Alberta. In North America the disease is spread from tree to tree by two species of elm bark beetles: native elm bark beetle (*Hylurogopinus rufipes* (Eichh.)) (Fig. 40A) and the smaller European elm bark beetle (*Scolytus multistriatus* (Marsh.)) (Fig. 40B). The native elm bark beetle is the major species in the prairie provinces; the European elm bark beetle has only been found in a few locations in Manitoba since 1979. The native elm bark beetle occurs in several natural stands of elm in Saskatchewan, but no elm beetle has yet been detected in Alberta. The only native elm species in the region, white elm or American elm (*Ulmus americana* L.), and all introduced elm species are known to be susceptible, but Siberian elm (*U. pumila* L.) and Japanese elm (*U. parvifolia* Jacq.) are known to have some degree of resistance.

Symptoms and Signs

Sudden wilting of young leaves in the upper crown of the infected trees is the first visible symptom of the disease in the early summer (Fig. 40C). Wilted leaves shrivel and turn brown but often persist on the tree until winter (Fig. 40D). When the symptoms appear after the leaves are fully mature, leaves turn yellow and usually drop prematurely. These late-season symptoms are often difficult to distinguish from natural autumn coloring.

Dark brown discoloration of the outer sapwood of infected stems is a characteristic internal symptom of the disease (Fig. 40E). Xylem vessels and surrounding cells are discolored and appear as dark rings on cross sections of infected stems.

Two kinds of fruiting structures, synnemata and perithecia, can be found in the brood galleries of the beetle. A synnema is a pinhead-like structure having a black stem with white mucilaginous droplets containing conidia at the top (Fig. 40F). A perithecium is a black structure with a globose base and a long neck. Ascospores are produced inside perithecia and ooze out from the tip of the neck.

Disease Cycle

This disease is carried from tree to tree by the bark beetles, which act as vectors. When young adults or overwintering adults emerge from the bark of diseased trees, they carry spores (mostly conidia) of the pathogen from the galleries. They feed (and mate) in the crotches of small twigs and deposit spores into the excavated cavities. Once inside the tree the pathogen spreads in the vascular system. Females bore beneath the bark of large stems and attract other beetles of the same species over long distances. After mating, females construct galleries (tunnels) in the cambium layer and lay eggs (Fig. 40G). The larvae, which hatch from the eggs, construct their galleries (Fig. 40F) and produce oval pupal chambers. A toxin called cerato-ulmin produced by the pathogen has been shown to be responsible for wilting of the tree. Root grafts between diseased and healthy trees are also considered to be responsible for the spread of this disease.

Damage

This disease has been known to kill elm trees of all ages, but overmature, stressed, or weakened trees attract beetles more than young, vigorously growing trees and are more often killed by the disease. Since large fully mature elm trees are valuable and highly regarded in urban situations, farm shelterbelts, and natural stands, mortality of these trees by DED is often a major concern.

Continued on next page.

Figure 40. Dutch elm disease, *Ceratocystis ulmi*. A, B. Two beetle vectors: a native elm bark beetle, *Hylurogopinus rufipes* (A), and a smaller European elm bark beetle, *Scolytus multistriatus* (B). **C.** A recently attacked tree with yellow wilting leaf symptom. **D.** A tree attacked for several years, showing progressive mortality of branches. **E.** Cross section of an infected young stem showing brown discoloration of the outer sapwood. **F.** New galleries developed by hatched larvae. **G.** A female gallery with eggs (shiny dots) deposited in the wall.

Control

Several preventive and control measures are used for this disease, with sanitation cutting and burning used most commonly. Insecticide spraying of bark beetles, fungicide injection, and root graft separation have also been employed.

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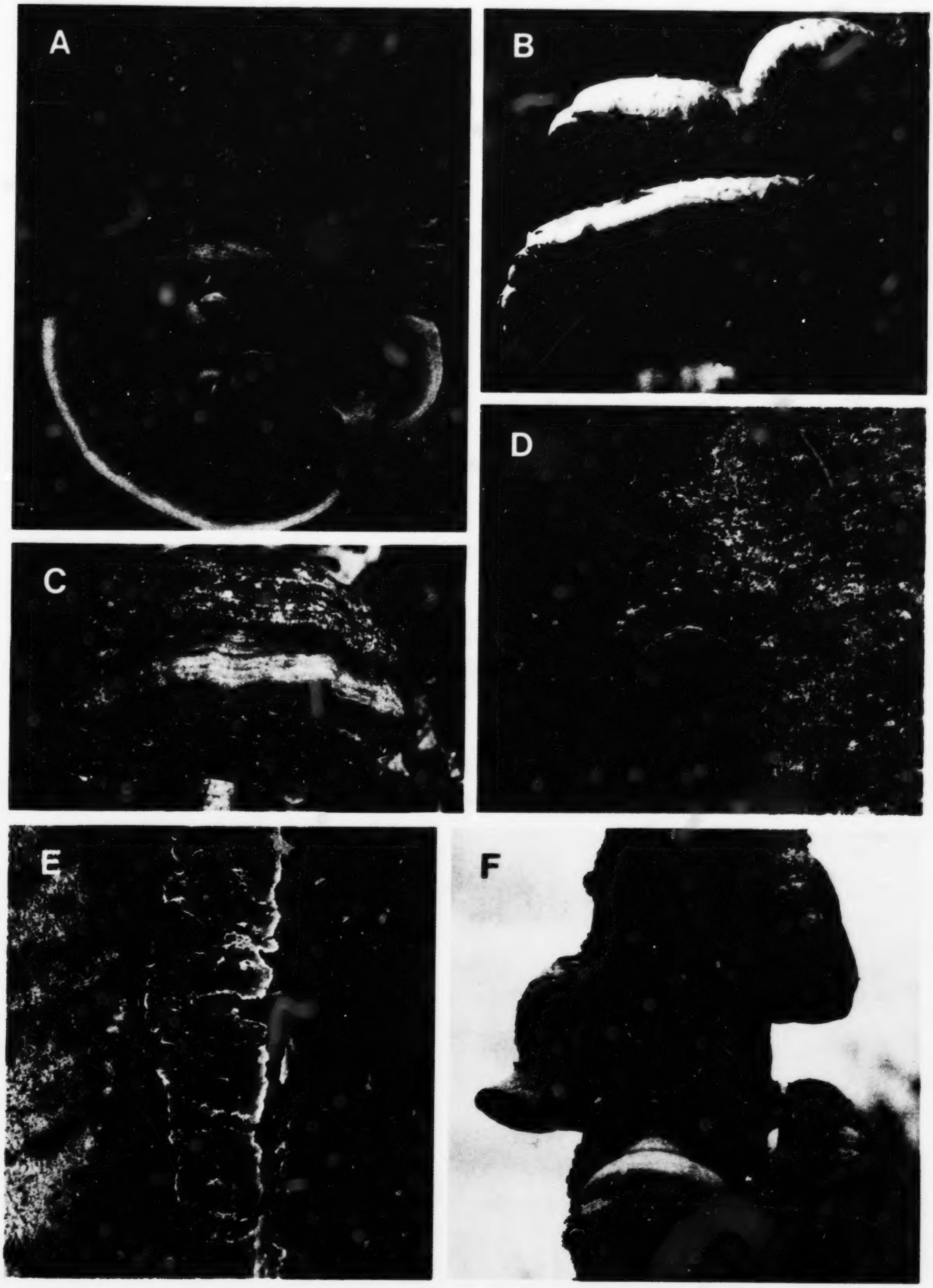
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DECAY OF ASPEN, BALSAM POPLAR, AND OTHER BROADLEAF TREES

Cause

Many species of fungi belonging to the class Basidiomycetes are responsible for decay of roots, butts, and trunks of aspen (*Populus tremuloides* Michx.), balsam poplar (*P. balsamifera* L.), and other broadleaf trees in the prairie provinces (Figs. 41A–F). More than 250 species of fungi are known to be associated with the decay of aspen in North America. Seventeen of the most common decay fungi of broadleaf trees in the region are listed in Table 8 (p. 110–111). *Phellinus tremulae* (Bond.) Bond. & Boriss. (Fig. 41D) and *Peniophora polygonia* (Pers.:Fr.) Boud. (Fig. 41E) on aspen are the two economically most important decay organisms in the prairie provinces.

Distribution and Hosts

All species listed in Table 8 occur throughout the region and are commonly associated with decayed and discolored wood of broadleaf trees.

Symptoms and Signs

Preferred part of the wood (heartwood or sapwood), location of decay (root, butt, trunk, etc.), type of decay (white rot or brown rot), or pattern of decay (e.g., pocket rot, stringy rot, or cubical rot) are specific to each decay organism (see Table 8). Also, each fungus produces characteristic fruiting bodies (conks, mushrooms, etc.). When fruiting bodies are not associated with the decay, cultural and microscopical characteristics of the fungus are necessary for positive identification.

Disease Cycle

Airborne basidiospores produced on the fruiting bodies (e.g., conks or mushrooms) of decay fungi are the major means of dissemination. New infections are initiated through branch stubs or various kinds of stem wounds that may be caused by animals, machines, hail, or frost. A few species that cause butt rot and root rot can also spread through soil or root contacts.

Damage

Excessive advanced decay is a factor limiting the economical utilization of broadleaf trees, especially aspen and balsam poplar, in the prairie provinces. Trees with significant advanced decay are not only unmerchantable for structural timber but, because their stems are weak and easily broken by winds or the weight of snow, are undesirable as windbreak or amenity trees. Staining of wood or the presence of incipient (early stages of) decay also make the tree undesirable, even though it may be mechanically sound. Although the amount of decay is known to increase with age of the stand, other factors, especially extensive stem damage (animal, weather, or mechanical), may also play an important role in the total amount of decay in a stand.

Control

No control measure is currently considered to prevent or control decay of hardwood trees in the prairie provinces. In intensively managed high-value stands the following procedures will minimize loss from decay: avoidance of mechanical stem injuries, proper pruning of branches, and early harvesting of stands before they reach unacceptable levels of decay. There is a strong indication that significant clonal differences in amount of decay exist in aspen; this may become an important factor to be considered in future genetic improvement programs of aspen or balsam poplar.

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Wall, R.E. 1971. Variation in decay in aspen stands as affected by their clonal growth pattern. Can. J. For. Res. 1:141–148.

Figure 41. Decay of aspen (*Populus tremuloides*), balsam poplar (*P. balsamifera*), and other broadleaf trees. A. *Ganoderma applanatum* on balsam poplar. **B.** *Pholiota destruens* on American elm, *Ulmus americana*. **C.** *Fomes fomentarius* on birch, *Betula* spp. **D.** *Phellinus tremulae* on aspen. **E.** *Peniophora polygonia* on aspen. **F.** *Piptoporus betulinus* on birch.

Table 8. Descriptions of common decay fungi of broadleaf trees in the prairie provinces

Organism	Type of decay	Fruiting body
Armillaria obscura (Pers.) Herink = *A. ostoyae* (Romag.) Herink **Shoestring root rot, honey mushroom** (See Armillaria Root Rot)	Light yellow to white spongy root and butt rot; surface of decay hollow; often with dark brown wall	Honey to brown-colored gilled mushroom with ring (annulus) on stem (Figs. 23A, F)
Bjerkandera adusta (Willd.:Fr.) Karst. ≡ *Polyporus adusta* Willd.:Fr. **Scorched conk**	White cubical sap rot	Shelving to sometimes resupinate; up to 7 cm wide; thin upper surface whitish to tan; often dark margins
Cerrena unicolor (Bull.:Fr.) Murr. ≡ *Daedalea unicolor* Bull.:Fr.	White spongy mottled rot of dead sapwood	Shelving; up to 7 cm wide; upper surface gray, hairy, often with green algae; lower surface whitish with maze-like pores
Coriolus hirsutus (Wulf.:Fr.) Quél. ≡ *Polyporus hirsutus* Wulf.:Fr. **Hairy conk**	White soft spongy rot	Shelving, thin, leathery; up to 5 cm wide; upper surface hairy, gray to brownish gray; lower surface yellowish with small pores
Coriolus versicolor (L.:Fr.) Quél ≡ *Polyporus versicolor* L.:Fr.	White soft spongy rot of dead sapwood	Shelving, thin, leathery, tough; up to 5 cm wide; upper surface distinct multicolored (brown, purple, gray) bands with velvety hairs; undersurface white with small pores
Flammulina velutipes (Curt.:Fr.) Sing. ≡ *Collybia velutipes* Curt.:Fr.	White heart rot	Mushroom; up to 7 cm wide; pale buff to orange-brown; centrally stiped
Fomes fomentarius (L.:Fr.) Kickx ≡ *Polyporus fomentarius* L.:Fr. **Tinder conk**	Mottled white trunk rot	Perennial, hoof-shaped, tough, woody conk; upper surface light gray; similar to but smaller than *Phellinus tremulae* and paler (Fig. 41C)
Ganoderma applanatum (Pers. ex Wallr.) Pat. ≡ *Elfvingia applanatum* (Pers. ex Wallr.) Karst. **Artist's conk**	White mottled spongy root and butt rot	Hard conk up to 70 cm wide; upper surface crusty gray to light brown, dark brown where bruised (Fig. 41A)
Gymnopilus spectabilis (Fr.) Sing. ≡ *Pholiota spectabilis* (Fr.) Gill	White rot	Yellowish orange gilled mushroom; up to 18 cm in diameter
Hirschioporus paragamenus (Fr.) Bond. & Sing. ≡ *Polyporus paragamenus* Fr.	White pocket sapwood decay, honeycomb appearance on cross sections	Annual, small, thin, shelving; less than 3 cm wide; upper surface white to buff; lower surface deep purple with small tubes

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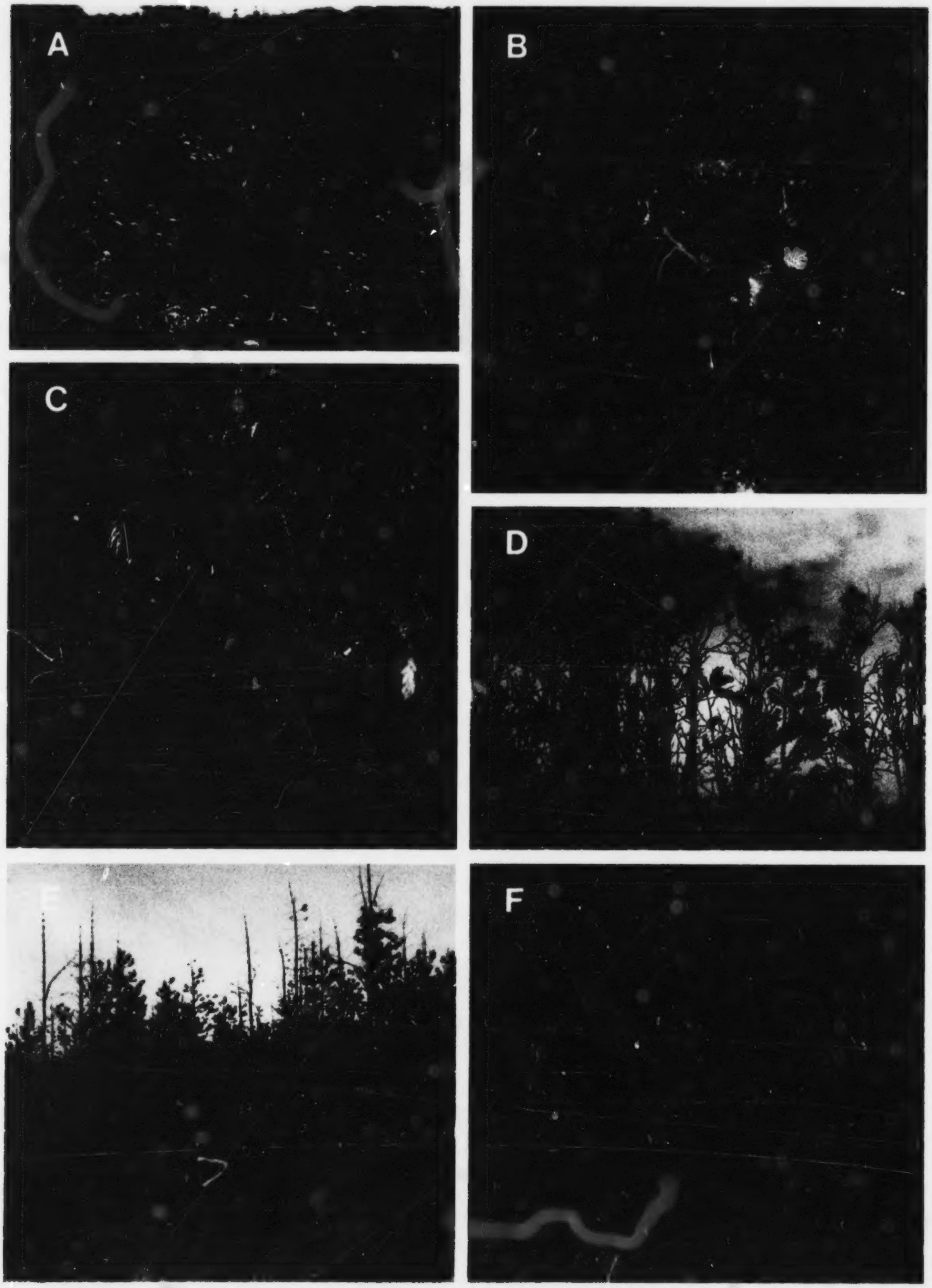
Table 8. Continued

Organism	Type of decay	Fruiting body
Lyophyllum ulmarium (Bull.:Fr.) Kuehn. ≡ *Pleurotus ulmarium* (Bull.:Fr.) Kumm.	White rot	Olive-gray to gray-brown mushroom; up to 25 cm in diameter; eccentric hairy stem; white gills
Peniophora polygonia (Pers.:Fr.) Boud. ≡ *Corticium polygonia* Pers.:Fr.	White rot	Pinkish red, disk-like patches with smooth hymenial layer; margin white (Fig. 41E)
Phellinus tremulae (Bond.) Bond. & Boriss. = *Fomes igniarius* (L.:Fr.) Kickx **False tinder conk**	White trunk rot with conspicuous black zone lines surrounding each decay colum	Perennial, hoof-shaped conk; up to 12 cm wide; upper surface blackish, cracked (Fig. 41D)
Pholiota destruens (Brond.) Quél.	White rot	Whitish mushroom; 8–20 cm in diameter; coarse, white wooly scales, domed (Fig. 41B)
Pholiota squarrosa (Pers.:Fr.) Kumm.	White mottled root and butt rot	Small, pale straw-yellow mushroom with rust-brown scales; cap up to 15 cm in diameter
Piptoporus betulinus (Bull.:Fr.) Karst. ≡ *Polyporus betulinus* Bull.:Fr.	Light brown crumbly rot	Shelving; thick, soft, corky conk with lateral stalk; incurved margin; upper surface white to gray (Fig. 41F)
Radulodon americanus Ryv. = *Radulum casearium* (Morg.) Lloyd	White stringy heart rot	Resupinate; teeth-like projections; thick (up to 3 cm)

NONINFECTIOUS DISORDERS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CLIMATIC DAMAGE

Cause

Because of the subarctic continental climate, many types of winter-related tree damage are common in the prairie provinces. Low winter temperature alone can damage trees, but various combinations of climatic conditions such as alternation of freezing and thawing, sun exposure followed by cold temperature, unusually late frost in the spring or early frost in the fall (Figs. 42A-D), or wind exposure during winter can cause winter damage. In recent years it has been suggested that certain species or strains of surface (epiphytic) microorganisms such as bacteria and yeasts are important frost damage initiators or enhancing agents (ice-nucleating agents, INA). In addition, damage by hail (Fig. 42E) and snow can be significant. Dead trees in round patches are observed from time to time and are speculated to be caused by lightning strikes (Fig. 42F). Red belt, which is also considered to be caused by adverse winter conditions, is discussed separately (see Red Belt).

Distribution and Hosts

The prairie provinces of Canada have severe winter climatic conditions, and various kinds of winter damage to forest trees are common across the region. The occurrence and extent of the damage are, however, influenced by climatic condition, topography of the site or alteration of exposure factors (such as logging, fire, or road construction), and the tree species involved.

Symptoms

Some of the common symptoms of winter damage are dieback, browning, reddening, or yellowing of conifer foliage (Fig. 42A), stem cracks and cankers, sudden wilting, proliferation (Fig. 42D) and death (Fig. 42B) of buds, formation of excessive suckers, and sudden death of new conifer shoots (Fig. 42C).

Damage

Winter damage can occur on trees of all species and of all ages. The damage may be localized, affecting a small number of trees, or can cover a vast area of many hectares of forest. Greenhouse-grown, containerized seedlings that are overwintered outside are often severely damaged. Lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) seedlings are known to be more susceptible to winter injury than white spruce (*Picea glauca* (Moench) Voss) seedlings.

Control

No direct control measure is available or recommended for winter damage, but preventive measures such as planting of winter-hardy species in high-hazard areas or avoidance of unnecessary exposure of overwintering nursery stock to adverse weather conditions should minimize the damage.

Selected References

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Figure 42. Climatic damage. **A.** Young white spruce, *Picea glauca*, affected by frost injury. **B.** A bud of white spruce killed by frost. **C.** Late frost damage to young foliage of white spruce. **D.** Patchy foliage of aspen, *Populus tremuloides*, caused by frost damage. **E.** Severe hail damage of lodgepole pine, *Pinus contorta* var. *latifolia*. **F.** Circular group tree mortality of lodgepole pine, likely resulting from a lightning strike.

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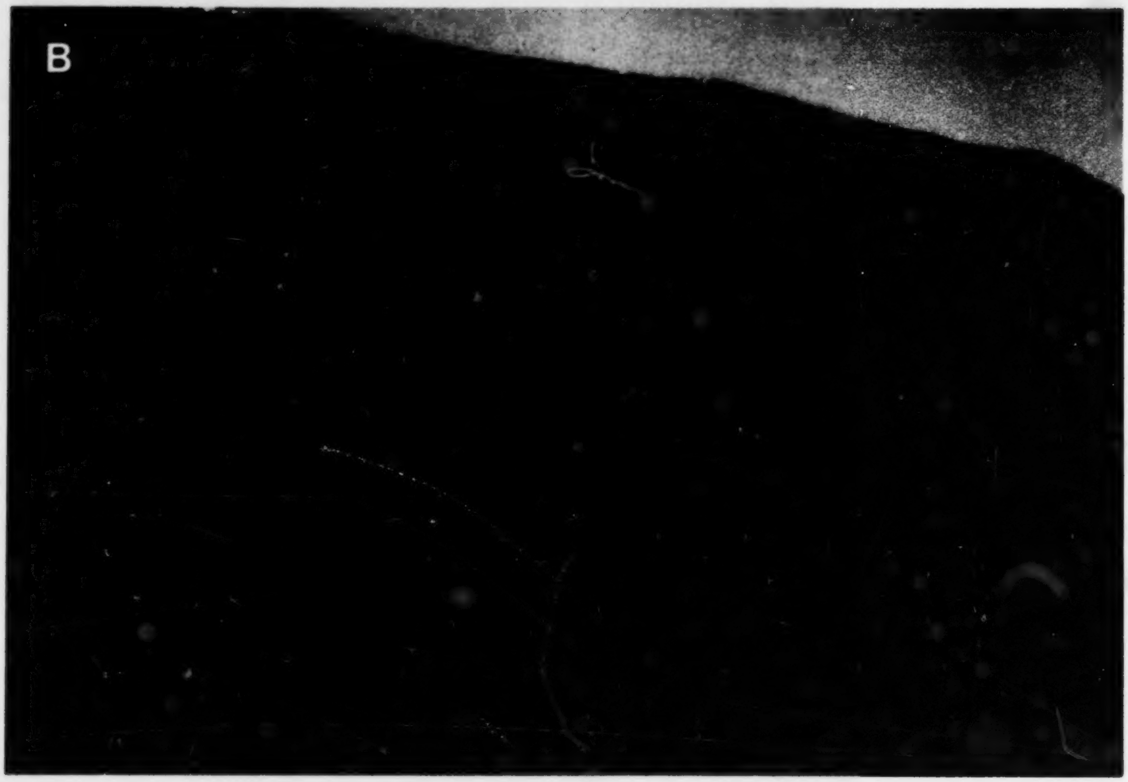
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RED BELT

Cause

Red belt is a phenomenon whose precise cause is not known. It is thought to be caused by a combination of climatological conditions; no infectious biological agent is involved. Drastic change of air temperature during the winter caused by warm chinook conditions are speculated to be responsible for red belt.

Distribution and Hosts

Red belt damage occurs mainly in the upper foothills of the eastern slopes of the Rocky Mountains in our region, but it is also known to occur in British Columbia and the western United States. Although all native conifers are affected, lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) is the most susceptible tree species in our region.

Symptoms

Symptoms of red belt usually appear in early spring on forested slopes as areas of reddish brown discoloration of various shapes and sizes (Figs. 43A, B). South- and west-facing slopes are most affected by red belt. On long slopes the damage often appears as horizontal, well-defined bands, thus the name "red belt". More commonly, damage occurs in distinct patches in the middle of slopes, along mountain ridges, and occasionally in valley bottoms. Red belt appears also along the fringes of stand openings.

Needles and buds of a whole tree can be killed, but most of the time buds are not killed and the affected tree recovers within a few years of attack. Often only a part or one side of a tree is affected.

Damage

Although mortality is rare, very severe red belt damage or repeated occurrence of the damage at the same location could kill significant numbers of trees. Mortality of approximately 7000 hectares of mature and immature lodgepole pine in the Cadomin area of the Alberta upper foothills of the Rocky Mountains was attributed to red belt in 1971. Trees weakened by red belt become vulnerable to bark beetle attack or root rot infection. Since red belt usually occurs on steep slopes in inaccessible areas, it has little economic significance. When trees are killed over large areas, however, dead needles on the trees make them extremely flammable and create increased fire hazards.

Control

Red belt is a result of natural phenomena, and no control is possible. Nevertheless, it is recommended that if red belt damage occurs in large areas, all merchantable timber should be salvaged before decay sets in. Because dead and dry timber can create fire hazards, salvage cutting may also help reduce this danger.

Selected References

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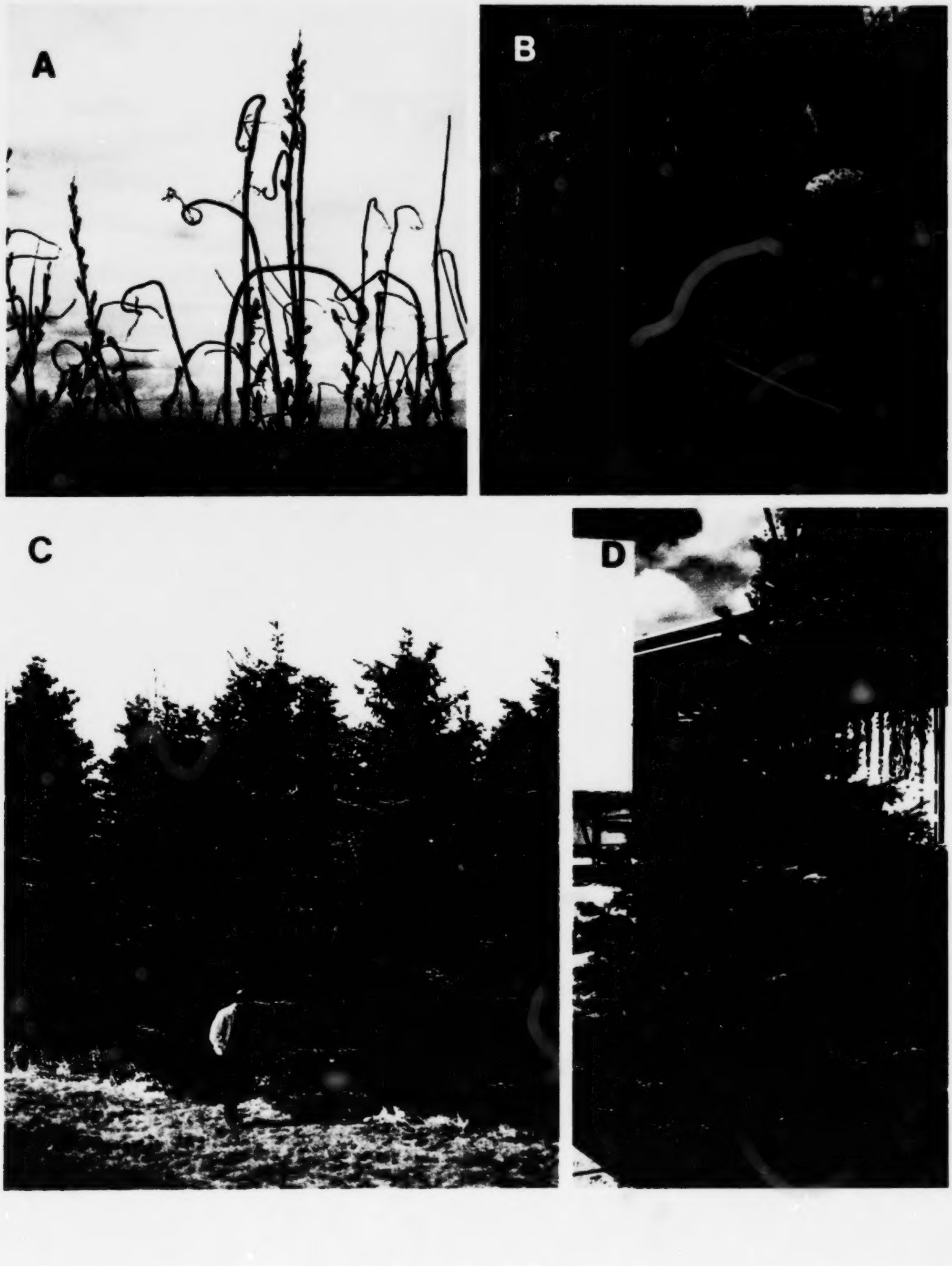
Figure 43. Red belt. A. An extensive red belt affecting most of a hillside. **B.** Two bands of red belt on a hill.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DAMAGE CAUSED BY HERBICIDES, SOIL STERILANTS, AND OTHER AGRICULTURAL CHEMICALS

Cause

Damage caused by misuse and abuse (improper use or overuse) of herbicides (Figs. 44A, B), soil sterilants (Figs. 44C, D), and other agricultural chemicals has been increasingly conspicuous during recent years.

Distribution and Hosts

All tree species are susceptible to damage by herbicides and other agricultural chemicals. Damage is common on urban trees, farm shelterbelts, and forest trees close to agricultural fields and under power lines. In recent years, herbicide use in forestry practice has been considered widely in Canada and poses some new concerns.

Symptoms

Symptoms vary depending on the kind and concentration of the chemicals, frequency of use, species and condition of trees, and the timing of the application. Some of the common symptoms are wavy or curled leaf margins, chlorosis, abnormal swelling, twisting and curling of branchlets (Fig. 44A), blight and necrosis of leaves (Fig. 44B), and browning and casting of conifer needles (Figs. 44C, D) or deciduous tree leaves.

Damage

Partial or total mortality of trees may occur. Also, indirect effects to mycorrhizal fungi and to shrub tree species such as buffalo-berry (*Shepherdia* spp.), sweet gale (*Myrica gale* L.), and alder (*Alnus* spp.), which are known to aid soil fertility of the stand with actinorrhizae, should also be considered.

Control

Only preventive measures can eliminate or reduce damage caused by these chemicals. Proper use of chemicals, including timing and method of application, protection of nontarget vegetation, and consideration of accumulated effects, are important to minimize the damage. It is advised that while using these chemicals one should strictly follow the directions on the package or the bottle.

Selected References

Malik, N.; Vanden Born, W.H. 1986. Use of herbicides in forest management. Can. For. Serv., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-282.

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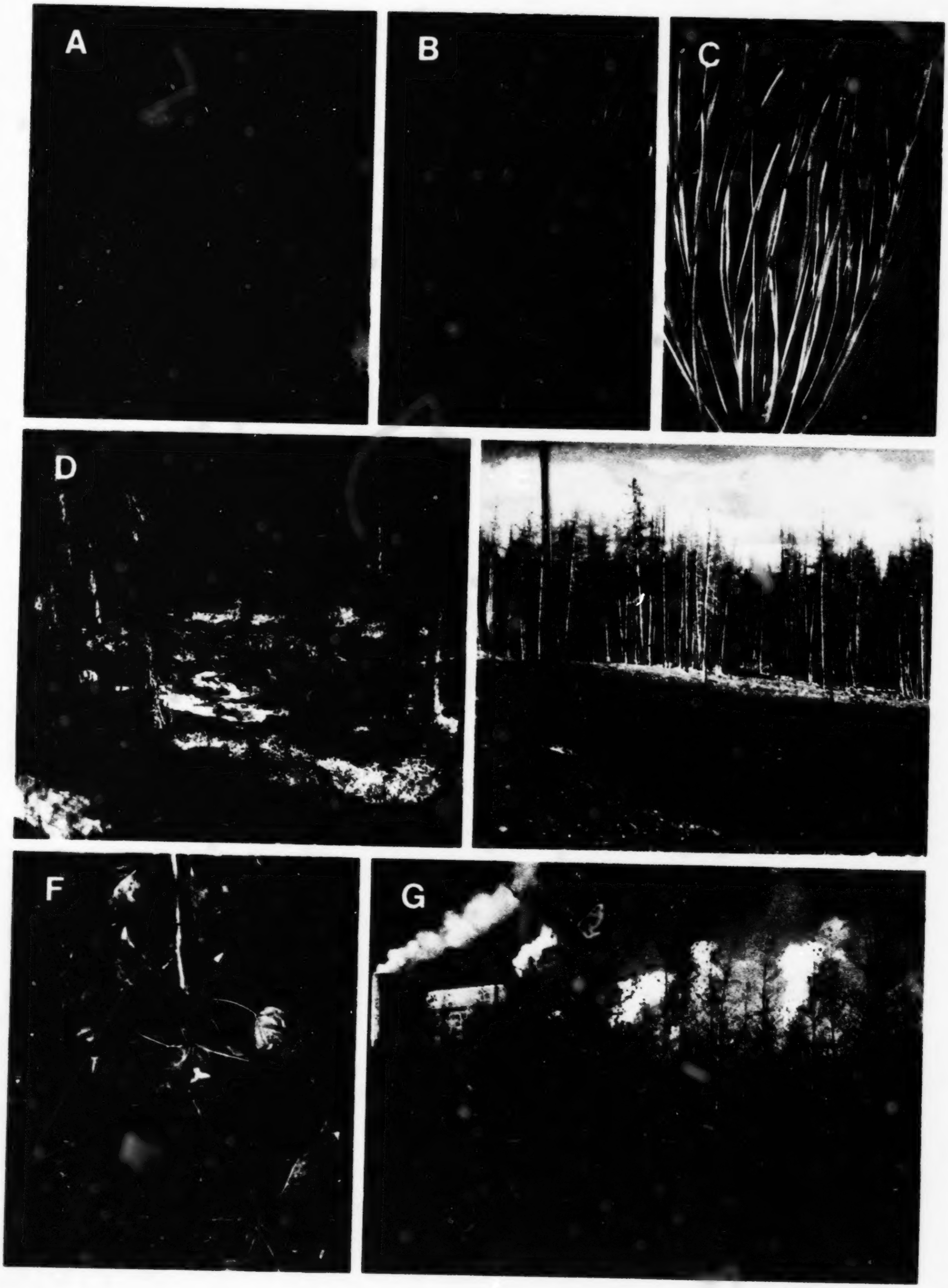
Yarish, W. 1980. Recognizing herbicide action and injury. Alberta Agriculture, Edmonton, Alberta. Agdex 641-7.

Figure 44. Damage caused by herbicides, soil sterilants, and other agricultural chemicals. A. Herbicide damage to willow, *Salix* spp. **B.** Foliar symptoms of aspen, *Populus tremuloides*, caused by a herbicide spray. **C.** Several white spruce, *Picea glauca*, affected by soil sterilant treatment along a fence line. **D.** Domestic white spruce affected by soil sterilant application.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CHEMICAL POLLUTANT DAMAGE

Cause

When trees are exposed for a long time to high concentrations of chemical pollutants in the environment they may die or exhibit various types of damage. The pollutants may be gaseous, liquid, or solid, being emitted from one or many industrial sources, including oil and gas extraction facilities, coal mining, mineral mining and smelting, and pulp and paper industry (Figs. 45A–G). Exhaust gas from gasoline and diesel engines, mainly from automobiles, also contains a significant amount of chemical pollutants. Another source of chemical pollution results when large amounts of gaseous oxides of nitrogen and sulfur are dissolved in rain water, producing acid rain or acid precipitation.

The following are the main chemical pollutants that can harm trees, along with their major sources:

Natural gas and oil refining: SO_2, H_2S, liquid hydrocarbons, saltwater spills
Metal mining and smelting: SO_2, heavy metals, particulates, fluorides
Other minerals: cement, potash
Pulp and paper industry: H_2S, methyl mercaptan, dimethyl sulfide, sodium hydroxide, ammonia
Stationary combustion engines: nitrogen oxides, ozone, PAN (peroxyacetyl nitrate)

Distribution and Hosts

Damage to forest trees by chemical pollutants is usually restricted to areas close to industries emitting toxic substances (Figs. 45E, G) or along heavily traveled highways; however, the effects of acid rain are known to be spread over long distances and wide areas. In the prairie provinces most natural gas wells are located on the eastern slopes of the Rockies; oil sand plants are in northern Alberta; oil refineries are near Edmonton, Regina, and Calgary; pulp and paper companies are located in Grande Prairie, Hinton, Prince Albert, The Pas, and Pine Falls; potash mines are located in southern Saskatchewan; and heavy metal processing plants are located in the Flin Flon and Thompson areas of Manitoba.

Symptoms

The type of damage and severity of symptoms depend on the kind, concentration, and exposure time of pollutants and the species, age, health, vigor, and seasonal developmental stage of host plants. Some of the major symptoms associated with chemical pollutant damage are chlorosis (Fig. 45C), necrosis, discoloration (Figs. 45A, B, F), wilting, dieback, and premature defoliation (Fig. 45G). A slow progressive decline in the health of trees over large areas has been reported in the eastern United States and Europe; chemical pollution is thought to be involved.

Damage

Damage to forest trees caused by chemical pollutants does not appear to be significant in the prairie provinces at the present time except in very localized areas; however, careful monitoring of areas around major point source locations is important to forewarn of future damage.

Control

The amount of tree damage caused by chemical pollutants can only be reduced by prevention. Planting of pollution-resistant tree species in high-hazard areas may be advisable and practical in some situations. Also, plantations of susceptible species should be established away from pollution sources.

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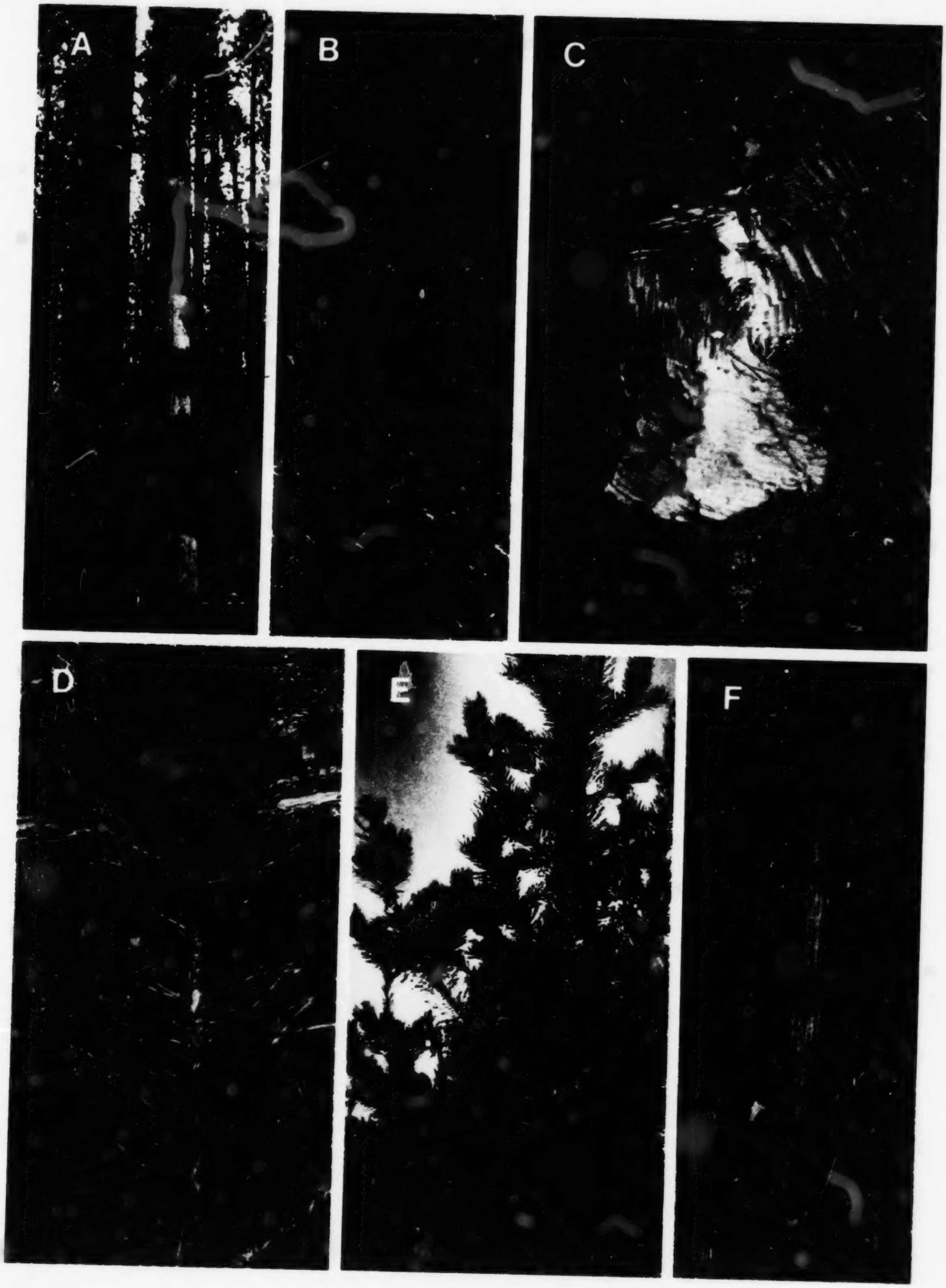
Figure 45. Chemical pollutant damage. A. Acute SO_2 fumigation injury to lodgepole pine, *Pinus contorta* var. *latifolia*. **B.** Close-up of acute SO_2 fumigation injury on lodgepole pine showing symptom development from the needle tips. **C.** Typical fluoride injury to jack pine, *P. banksiana*, near an aluminum smelter. **D.** Elemental sulfur damage of ground-cover vegetation near sulfur piles. **E.** Extensive tree mortality around a well blowout. **F.** Symptoms on aspen, *Populus tremuloides*, from a single acute exposure to metal smelter emissions. **G.** Jack pine affected by emissions from a pulp mill.


A
B
C
D
E
F

ANIMAL DAMAGE

Cause

Many species of small and large mammals damage forest trees in the prairie provinces (Figs. 46A–F). The two animals known to cause the most damage to young conifer trees in managed forests are snowshoe hare (*Lepus americanus* Erxleben) and red squirrel (*Tamiasciurus hudsonicus* Erxleben). Other animals that damage forest trees in this region are porcupine (*Erethizon dorsatum* Cuvier), beaver (*Castor canadensis* Khul.), elk (*Cervus canadensis nelsoni* Bailey), deer (*Odocoileus* spp.), moose (*Alces alces* Gray), and bear (*Euarctos* spp. and *Ursus* spp.). Small mammals such as white-footed mouse (*Peromyscus maniculatus borealis* Mearns.), meadow vole (*Microtus pennsylvanicus*), red-backed vole (*Clethrionomys gapperi*), chipmunk (*Eutamias* spp.), and shrew (*Sorex* spp.) are known to damage conifer seeds on the ground.

Distribution and Hosts

Intensity, distribution, and types of animal damage are dependent on the population level and kinds of animals involved, availability of other food sources for the animals, species and age of trees, and climatic and biotic conditions of the general area. Some species of animals have definite annual patterns of population increase and decrease. For example, the snowshoe hare is known to reach peak population levels every 9-10 years.

Symptoms

Typical symptoms of damage by various animals are given below:

Root clipping and basal stem debarking: vole
Stem debarking of young trees: snowshoe hare, squirrel
Seedling clipping: vole, snowshoe hare, squirrel
Foliage clipping and browsing: elk, deer, moose
Mature tree debarking: bear, elk, deer, porcupine (Figs. 46A, B, F)
Large tree cutting: beaver (Fig. 46C)
Seed destruction: white-footed deer mouse, meadow vole, chipmunk, shrew
Cone (branch) clipping: squirrel (Figs. 46D, E)

Damage

Damage by animals, especially by snowshoe hare and red squirrel, is significant in young managed conifer stands. Cumulative damage by the two animals involving 40–50% of young trees is common. Aside from mortality and disfigurement of trees, animal feeding leaves scars that often provide entry courts for canker-causing or wood decay fungi. Stem rust cankers of pines are known to be selectively gnawed by rodents and rabbits. Significant amounts of seeds on the forest floor are also destroyed by small animals before germination. This is considered to be the most important problem facing direct seeding operations for conifers.

Control

To minimize damage by snowshoe hare in young conifer stands, preventive measures such as habitat manipulation (including herbicides) to reduce suitable habitat for the animal, planting large (taller than 50 cm) seedlings, use of rabbit repellent, toxic baiting, shooting and trapping, and biological control using predators and diseases have been suggested, but none has been used extensively in the prairies. The unpredictable nature of the damage makes implementation of preventive and control measures difficult. Coating of conifer seeds with animal repellents has been developed to protect seeds from being destroyed by small mammals.

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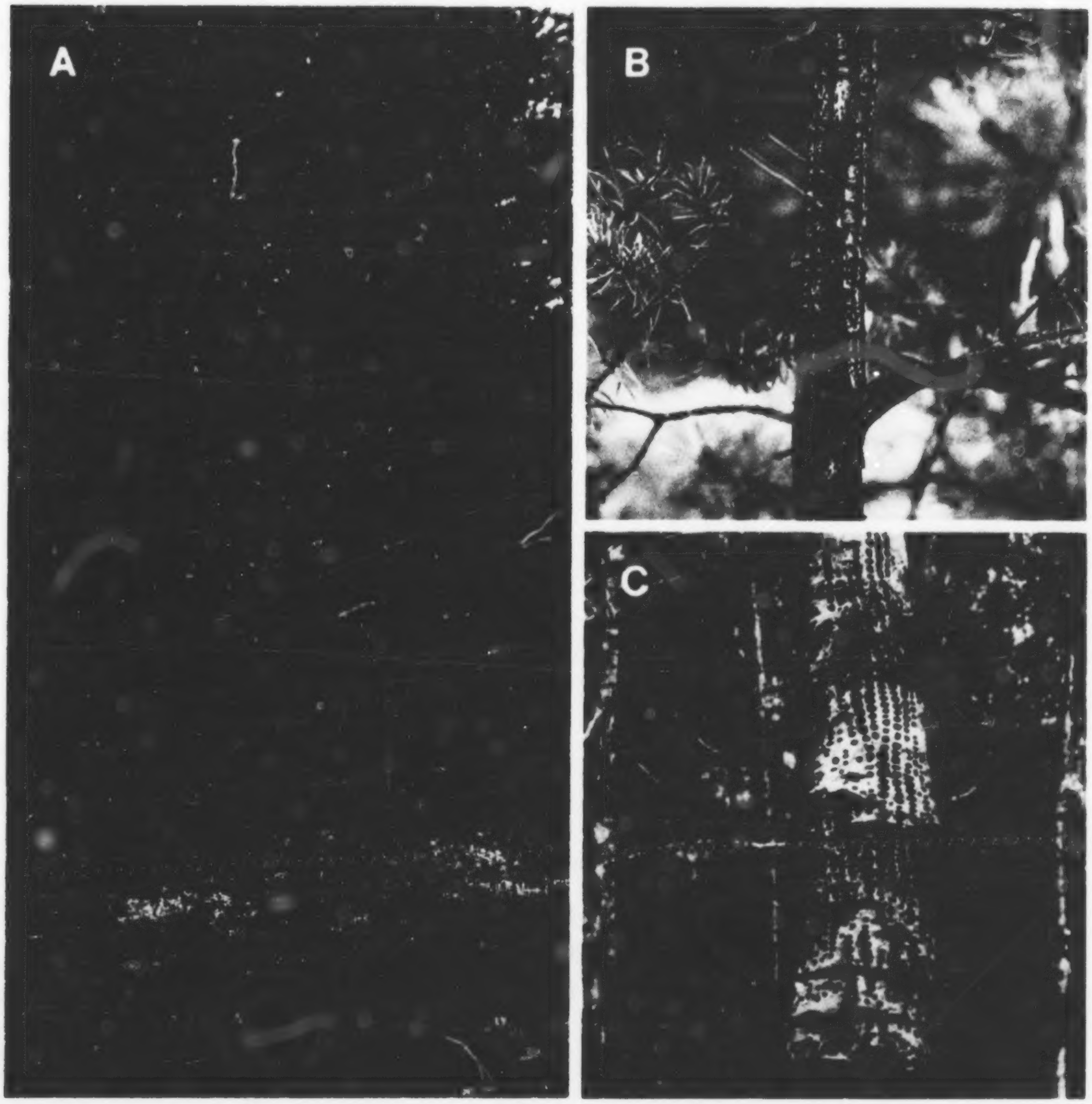
Figure 46. Animal damage. A. Extensive bark injury of lodgepole pine, *Pinus contorta* var. *latifolia*, caused by porcupine. **B.** Bark injury to lodgepole pine, probably caused by deer. **C.** A balsam poplar, *Populus balsamifera*, cut down by beaver. **D.** Close-up of injury caused by cone clipping by squirrel. **E.** Red flagging of lodgepole pine caused by cone clipping by squirrel. **F.** Debarking injury of lodgepole pine caused by bear.


A
B
C

SAPSUCKER INJURY

Cause

Injury to trees can be caused by the yellow-bellied sapsucker (*Sphyrapicus varius varius* L.), a migratory member of the woodpecker family measuring 20–25 cm in length. The crown and throat are crimson and the rest of the head is black with white streaks above and below the eye extending onto the neck; the lower breast and abdomen are yellowish. There is a related species, the red-bellied sapsucker (*S. varius ruber* (Clem.)), in coastal British Columbia.

Distribution and Hosts

This bird lives throughout the mixed-wood forests of North America during the summer. The most common tree species in the prairie provinces, birch (*Betula* spp.), aspen (*Populus tremuloides* Michx.), and pines (*Pinus* spp.), can all be damaged by the yellow-bellied sapsucker.

Symptoms

The birds drill rows of holes on the bark of young trees through to the sapwood (Figs. 47A–C) and visit these trees periodically to lap up the sap that has oozed out of the holes. Holes drilled by the sapsuckers are always arranged in regular patterns (Figs. 47B, C).

Damage

If many holes are drilled by the bird, the trees can be weakened. Because sapsucker feeding trees are often found near the margins of recently logged areas or exposed sites near roadsides, there is some indication that the birds prefer trees already weakened. Sapsucker wounds provide entry points for stain-causing and decay fungi.

Control

The yellow-bellied sapsucker, like most other birds, is protected under the Migratory Birds Convention Act and may not be captured or killed. Noisemakers and frightening devices have been used to protect valuable trees in areas of high bird populations.

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Figure 47. Sapsucker injury. A, B. Extensively injured jack pine, *Pinus banksiana*. **C.** Extensively injured aspen, *Populus tremuloides.*

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APPENDIX 1

LIST OF DISEASES BY HOST

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LIST OF DISEASES BY HOST

***Abies* spp. (fir):**
- ***balsamea* (L.) Mill. (balsam fir)**
- ***lasiocarpa* (Hook.) Nutt. (alpine fir)**
- *Armillaria obscura* (Pers.) Herink (Armillaria root rot)
- *Herpotrichia juniperi* (Duby) Petr. (snow mold)
- *Herpotrichia coulteri* (Pk.) Bose
- *Hyalopsora aspidiotus* P. Magn. (needle rust)
- *Isthmiella abietis* (Dearn.) Darker (needle cast)
- *Isthmiella quadrispora* Ziller (needle cast)
- *Lirula abieti-concoloris* (Mayer ex Dearn.) Darker (needle cast)
- *Lophomerum autumnale* (Darker) Magasi (needle cast)
- *Melampsora abieti-capraearum* Tub. (needle rust)
- *Melampsorella caryophyllacearum* Schroet. (witches' broom rust)
- *Nothophacidium abietinellum* (Dearn.) Reid & Cain (snow blight)
- *Phacidium abietis* (Dearn.) Reid & Cain (snow blight)
- *Phaeocryptopus nudus* (Pk.) Petr. (needle spot)
- *Pucciniastrum epilobii* Otth (needle rust)
- *Pucciniastrum goeppertianum* (Kuehn) Kleb. (needle rust)
- *Sarcotrochila balsameae* (Davis) Korf (snow blight)
- *Uredinopsis phegopteridis* Arth. (needle rust)
- See also Conifers, decay fungi

***Acer negundo* L. var. *interius* (Britt.) Sarg. (Manitoba maple):**
- *Microsphaera penicillata* (Fr.) Lév. (powdery mildew)

***Alnus* spp. (alder):**
- ***crispa* (Ait.) Pursh (green alder)**
- ***tenuifolia* Nutt. (river alder)**
- *Erysiphe aggregata* (Pk.) Farl. (powdery mildew)
- *Microsphaera penicillata* (Fr.) Lév. (powdery mildew)
- *Phyllactinia guttata* (Fr.) Lév. (powdery mildew)
- See also Broadleaf trees, decay fungi

***Amelanchier alnifolia* Nutt. (saskatoon, serviceberry):**
- *Apiosporina collinsii* (Schw.) Hoehn. (black leaf and witches' broom)
- *Erwinia amylovora* (Burr.) Winsl. et al. (fire blight)
- *Gymnosporangium clavariiforme* (Pers.) DC. (berry and leaf rust)
- *Gymnosporangium clavipes* (Cke. & Pk.) Cke. & Pk. (berry and leaf rust)
- *Gymnosporangium nelsonii* Arth. (leaf rust)
- *Gymnosporangium nidus-avis* Thaxt. (leaf rust)
- *Phyllactinia guttata* (Fr.) Lév. (powdery mildew)

***Arctostaphylos rubra* (Rehder & Wils.) Fern. (alpine bearberry):**
- *Pucciniastrum sparsum* (Wint.) E. Fisch. (spruce-bearberry rust)

***Arctostaphylos uva-ursi* (L.) Spreng. (kinnikinnick):**
- *Chrysomyxa arctostaphyli* Diet. (yellow witches' broom of spruce)

***Aster* spp. (aster):**
- *Coleosporium asterum (Diet.) Syd. (pine needle rust)*

Broadleaf trees, decay fungi
- *Armillaria obscura* (Pers.) Herink. (Armillaria root rot)
- *Bjerkandera adusta* (Willd.:Fr.) Karst. (scorched conk)
- *Cerrena unicolor* (Bull.:Fr.) Murr. (white spongy mottled rot)
- *Coriolus hirsutus* (Wulf.:Fr.) Quél. (hairy conk)
- *Coriolus versicolor* (L.:Fr.) Quél. (white soft spongy rot)
- *Flammulina velutipes* (Curt.:Fr.) Sing. (white heart rot)
- *Fomes fomentarius* (L.:Fr.) Kickx (tinder conk)
- *Ganoderma applanatum* (Pers. ex Wallr.) Pat. (artist's conk)
- *Gymnopilus spectabilis* (Fr.) Sing.
- *Hirschioporus paragamenus* (Fr.) Bond. & Sing. (white pocket sapwood decay)
- *Lyophyllum ulmarium* (Bull.:Fr.) Kuehn. (white rot)
- *Peniophora polygonia* (Pers.:Fr.) Boud. (white rot)
- *Phellinus tremulae* (Bond.) Bond. & Boriss (false tinder conk)
- *Pholiota destruens* (Brond.) Quél. (white rot)
- *Pholiota squarrosa* (Pers.:Fr.) Kumm. (white mottled rot)
- *Piptoporus betulinus* (Bull.:Fr.) Karst. (light brown crumbly rot)
- *Radulodon americanus* Ryv. (white stringy heart rot)

***Castilleja* spp. (Indian paint-brush):**
- *Cronartium coleosporioides* Arth. (stalactiform blister rust of hard pines)

Cerastium **spp. (chickweed):**
- *Melampsorella caryophyllacearum* Schroet. (witches' broom rust of fir)

Comandra umbellata **(L.) Nutt. var. *pallida* (DC.) M.E. Jones (bastard toad-flax):**
- *Cronartium comandrae* Pk. (comandra blister rust of hard pines)

Comptonia peregrina **(L.) Coult. (sweet fern):**
- *Cronartium comptoniae* Arth. (sweet fern blister rust of hard pines)

Conifers, decay fungi
- *Anisomyces odoratus* (Wulf.:Fr.) Pat. (brown cubical pocket rot)
- *Armillaria obscura* (Pers.) Herink. (Armillaria root rot)
- *Coniophora puteana* (Schum.:Fr.) Karst. (brown cubical rot)
- *Echinodontium tinctorium* (Ell. & Ev.) Ell. & Ev. (Indian paint fungus)
- *Fomitopsis officinalis* (Vill.:Fr.) Bond. & Sing. (quinine conk)
- *Fomitopsis pinicola* (Sw.:Fr.) Karst. (red belt fungus)
- *Gloeophyllum saepiarium* (Wulf.:Fr.) Karst. (slash conk)
- *Haematostereum sanguinolentum* (Alb. & Schw.:Fr.) Pouzar (bleeding fungus)
- *Hirschioporus abietinus* (Dicks.:Fr.) Donk (purple conk)
- *Inonotus tomentosus* (Fr.) Gilbertson (Tomentosus root and butt rot)
- *Peniophora pseudo-pini* Weres. & S. Gibson (pink stain)
- *Phaeolus schweinitzii* (Fr.) Pat. (velvet top fungus)
- *Phellinus pini* (Thore:Fr.) Pil. (red ring rot)
- *Pholiota alnicola* (Fr.) Sing. (white rot)
- *Serpula himantoides* (Fr.) Bond. (brown cubical rot)

Cotoneaster **spp. (cotoneaster; introduced):**
- *Erwinia amylovora* (Burr.) Winsl. et al. (fire blight)
- *Stereum purpureum* (Pers.:Fr.) Fr. (silver leaf)

Crataegus **spp. (hawthorn):**
- *Erwinia amylovora* (Burr.) Winsl. et al. (fire blight)
- *Stereum purpureum* (Pers.:Fr.) Fr. (silver leaf)

Epilobium **spp. (fireweed):**
- *Pucciniastrum epilobii* Otth (fir needle rust)

Geocaulon lividum **(Richards.) Fern. (northern bastard toad-flax):**
- *Cronartium comandrae* Pk. (comandra blister rust of hard pines)

Gymnocarpium dryopteris **(L.) Newm. (oak fern):**
- *Hyalopsora aspidiotus* (P. Magn.) P. Magn. (fir needle rust)
- *Uredinopsis phegopteridis* Arth. (fir needle rust)

Juniperus **spp. (juniper):**
- ***communis*** **L. var. *depressa* Pursh (common juniper)**
- ***horizontalis*** **Moench (creeping juniper)**
- ***scopulorum*** **Sarg. (Rocky Mountain juniper)**
- *Gymnosporangium clavariiforme* (Pers.) DC. (stem rust)
- *Gymnosporangium clavipes* (Cke. & Pk.) Cke. & Pk. (stem rust)
- *Gymnosporangium nelsonii* Arth. (stem gall rust)
- *Gymnosporangium nidus-avis* Thaxt. (needle rust, causes witches' broom)
- *Herpotrichia juniperi* (Duby) Petr. (snow mold)

Larix **spp. (larch)**
- ***laricina*** **(Du Roi) K. Koch (tamarack)**
- ***lyallii*** **Parl. (alpine larch)**
- ***occidentalis*** **Nutt. (western larch)**
- *Gremmeniella abietina* (Lager.) Morelet (Scleroderris canker)
- *Melampsora medusae* Thuem. (needle rust)
- *Melampsora occidentalis* Jaks. (needle rust)
- See also Conifers, decay fungi

Ledum **spp. (Labrador tea):**
- *Chrysomyxa ledi* d By. (spruce needle rust)
- *Chrysomyxa ledicola* Lagh. (spruce needle rust)
- *Chrysomyxa woroninii* Tranz. (spruce shoot rust)

Malus **spp. (apple, crab apple):**
- *Erwinia amylovora* (Burr.) Winsl. et al. (fire blight)
- *Phyllactinia guttata* (Fr.) Lév. (powdery mildew)
- *Stereum purpureum* (Pers.:Fr.) Fr. (silver leaf)

Melampyrum lineare **Desr. (cow-wheat):**
- *Cronartium coleosporioides* Arth. (stalactiform blister rust of hard pines)

Moneses uniflora **(L.) A. Gray (one-flowered wintergreen):**
- *Chrysomyxa monesis* Ziller (spruce cone rust)
- *Chrysomyxa pirolata* Wint. (spruce cone rust)

Myrica gale **L. (sweet gale):**
- *Cronartium comptoniae* Arth. (sweet fern blister rust of hard pines)

Orthilia secunda **L. (one-sided wintergreen):**
- *Chrysomyxa pirolata* Wint. (spruce cone rust)

***Orthocarpus luteus* Nutt. (yellow owl-clover):**
- *Cronartium coleosporioides* Arth. (stalactiform blister rust of hard pines)

***Pedicularis bracteosa* Benth. (lousewort):**
- *Cronartium coleosporioides* Arth. (stalactiform blister rust of hard pines)

***Picea* spp. (spruce):**
- ***engelmannii* Parry (Engelmann spruce)**
- ***glauca* (Moench) Voss (white spruce)**
- ***mariana* (Mill.) B.S.P. (black spruce)**
- ***pungens* Engelm. (blue spruce; introduced)**
- *Arceuthobium americanum* Nutt. ex Engelm. (dwarf mistletoe)
- *Arceuthobium pusillum* Pk. (dwarf mistletoe)
- *Armillaria obscura* (Pers.) Herink (Armillaria root rot)
- *Botryotinia fuckeliana* (d By.) Whet. (gray mold)
- Burls (cause unknown)
- *Chrysomyxa arctostaphyli* Diet. (broom rust, yellow witches' broom)
- *Chrysomyxa ledi* d By. (needle rust)
- *Chrysomyxa ledicola* Lagh. (needle rust)
- *Chrysomyxa monesis* Ziller (cone rust)
- *Chrysomyxa pirolata* Wint. (cone rust)
- *Chrysomyxa weirii* Jacks. (needle rust)
- *Chrysomyxa woroninii* Tranz. (shoot rust)
- Damping-off (various fungi)
- *Dendroctonus ponderosae* Hopk. (mountain pine beetle)
- *Gremmeniella abietina* (Lager.) Morelet (Scleroderris canker)
- *Herpotrichia juniperi* (Duby) Petr. (snow mold)
- *Isthmiella crepidiformis* (Darker) Darker (needle cast)
- *Lirula macrospora* (Hartig) Darker (needle cast)
- *Lophodermium piceae* (Fckl.) Hoehn. (needle cast)
- *Lophophacidium hyperboreum* Lager. (snow blight)
- *Melampsora medusae* Thuem. (needle rust)
- *Melampsora occidentalis* Jacks. (needle rust)
- *Pucciniastrum americanum* (Farl.) Arth. (needle rust)
- *Pucciniastrum arcticum* Tranz. (needle rust)
- *Pucciniastrum sparsum* (Wint.) E. Fisch. (needle rust)
- *Stereum purpureum* (Pers.:Fr.) Fr. (silver leaf)
- *Storage molds* (various fungi)
- See also Conifers, decay fungi

***Pinus* spp. (hard pines):**
- ***banksiana* Lamb. (jack pine)**
- ***contorta* Dougl. var. *latifolia* Engelm. (lodgepole pine)**
- ***mugo* Turra (mugo pine; introduced)**
- ***resinosa* Ait. (red pine)**
- ***sylvestris* L. (Scots pine; introduced)**
- *Arceuthobium americanum* Nutt. ex Engelm. (dwarf mistletoe)
- *Armillaria obscura* (Pers.) Herink (Armillaria root rot)
- *Atropellis piniphila* (Weir) Lohman & Cash (Atropellis canker)
- *Botryotinia fuckeliana* (d By.) Whet. (gray mold)
- Burls (cause unknown)
- *Ceratocystis* spp. (blue stain fungi associated with mountain pine beetle)
- *Coleosporium asterum* (Diet.) Syd. (needle rust)
- *Cronartium coleosporioides* Arth. (stalactiform blister rust)
- *Cronartium coleosporioides* f. *album* Ziller (white-spored stalactiform blister rust)
- *Cronartium comandrae* Pk. (comandra blister rust)
- *Cronartium quercuum* (Berk.) Miy. ex Shirai (eastern gall rust, pine-oak gall rust)
- *Cronartium comptoniae* Arth. (sweet fern blister rust)
- Damping-off (various fungi)
- *Davisomycella ampla* (Davis) Darker (needle cast)
- *Dendroctonus ponderosae* Hopk. (mountain pine beetle)
- *Elytroderma deformans* (Weir) Darker (Elytroderma needle cast)
- *Endocronartium harknessii* (J. P. Moore) Y. Hirat. (western gall rust)
- *Gremmeniella abietina* (Lager.) Morelet (Scleroderris canker)
- *Hendersonia pinicola* Wehm. (needle spot)
- *Herpotrichia coulteri* (Pk.) Bose (snow mold)
- *Leptomelanconium cinereum* (Dearn.) Morgan-Jones (needle fungus)
- *Lophodermella concolor* (Dearn.) Darker (needle cast)
- *Lophodermella montivaga* Petr. (needle cast)
- *Lophodermium pinastri* (Shrad. ex Hook.) Chev. (needle cast)
- *Melampsora medusae* Thuem. (needle rust)
- *Melampsora occidentalis* Jacks. (needle rust)
- *Naemacyclus niveus* (Pers.:Fr.) Sacc. (needle blight)
- *Naemacyclus minor* Butin (needle blight)
- *Peridermium filamentosum* Pk. (limb rust)
- *Phaeoseptoria contortae* Parmelee & Y. Hirat. (needle fungus)
- *Thyriopsis halepensis* (Cke.) Th. & Syd. (needle spot)
- See also Conifers, decay fungi

***Pinus* spp. (soft pines):**
- ***albicaulis* Engelm. (whitebark pine)**
- ***flexilis* James (limber pine)**
- ***strobus* L. (eastern white pine)**
- *Bifusella linearis* (Pk.) Hoehn. (needle cast)
- *Cronartium ribicola* J. C. Fisch. ex Rab. (white pine blister rust)
- *Herpotrichia coulteri* (Pk.) Bose (snow mold)
- *Lophodermium nitens* Darker (needle cast)
- *Lophodermium pinastri* (Shrad. ex Hook.) Chev. (needle cast)
- *Naemacyclus niveus* (Pers.:Fr.) Sacc. (needle blight)
- See also Conifers, decay fungi

***Populus* spp. (aspen, poplar):**
- ***angustifolia* James (narrow cottonwood)**
- ***balsamifera* L. (balsam poplar)**
- ***deltoides* Marsh. (eastern cottonwood)**
- ***tremuloides* Michx. (aspen)**
- ***trichocarpa* Torr. & Gray (black cottonwood)**
- *Ciborinia whetzelii* (Seaver) Seaver (ink spot)
- *Diplodia tumefaciens* (Shear) Zalasky (Diplodia gall and rough-bark)
- *Hypoxylon mammatum* (Wahl.) J.H. Miller (Hypoxylon canker)
- *Linospora tetraspora* G. E. Thompson (leaf blight)
- *Marssonina balsamiferae* Y. Hirat. (leaf spot)
- *Marssonina populi* (Lib.) Magn. (leaf spot)
- *Marssonina tremuloides* Kleb. (leaf spot)
- *Melampsora medusae* Thuem. (leaf rust)
- *Melampsora occidentalis* Jacks. (leaf rust)
- *Mycosphaerella populicola* G. E. Thompson (leaf spot)
- *Mycosphaerella populorum* G. E. Thompson (leaf spot)
- *Rhytidiella moriformis* Zalasky (rough-bark)
- *Septogloeum rhopaloideum* Dean & Bisby (leaf spot)
- *Stereum purpureum* (Pers.:Fr.) Fr. (silver leaf)
- *Uncinula salicis* (DC. ex Mérat) Wint. (powdery mildew)
- *Venturia macularis* (Fr.) E. Muller & Arx (leaf and twig blight)
- *Venturia populina* (Vuill.) Fabric. (leaf and twig blight)
- See also Broadleaf trees, decay fungi

***Prunus* spp. (cherry, plum):**
- ***pensylvanica* L. f. (pin cherry)**
- ***virginiana* L. (choke cherry)**
- *Apiosporina morbosa* (Schw.) Arx (black knot)
- *Phyllactinia guttata* (Fr.) Lév. (powdery mildew)
- *Stereum purpureum* (Pers.:Fr.) Fr. (silver leaf)

***Pseudotsuga menziesii* (Mirb.) Franco (Douglas fir):**
- *Dendroctonus ponderosae* Hopk. (mountain pine beetle)
- *Gremmeniella abietina* (Lager.) Morelet (Scleroderris canker)
- *Melampsora medusae* Thuem. (needle rust)
- *Melampsora occidentalis* Jacks. (needle rust)

***Pyrola* spp. (wintergreen):**
- ***asarifolia* Michx. (common pink wintergreen)**
- *Chrysomyxa pirolata* Wint. (spruce cone rust)

***Pyrus* spp. (pear):**
- *Erwinia amylovora* (Burr.) Winsl. et al. (fire blight)
- *Phyllactinia guttata* (Fr.) Lév. (powdery mildew)
- *Stereum purpureum* (Pers.:Fr.) Fr. (silver leaf)

***Quercus* spp. (oak):**
- *Cronartium quercuum* (Berk.) Miy. ex Shirai (eastern gall rust, pine-oak gall rust)

***Rhinanthus crista-galli* L. (yellow rattle):**
- *Cronartium coleosporioides* Arth. (stalactiform blister rust of hard pines)

***Ribes* spp. (currant, gooseberry):**
- ***hudsonianum* Richards. (wild black currant)**
- ***lacustre* (Pers.) Poir. (bristly black currant)**
- *Cronartium ribicola* J. C. Fisch. ex Rab. (white pine blister rust)

***Rubus* spp. (raspberry):**
- *Erwinia amylovora* (Burr.) Winsl. et al. (fire blight)
- *Pucciniastrum americanum* (Farl.) Arth. (spruce-raspberry rust)
- *Pucciniastrum arcticum* Tranz. (spruce-raspberry rust)

Salix spp. (willow):
- *Ciborinia foliicola* (Cash & Davidson) Whetz. (black vein)
- *Melampsora abieti-capraearum* Tub. (fir needle rust)
- *Phyllactinia guttata* (Fr.) Lév. (powdery mildew)
- *Rhytisma salicinum* (Pers.) Fr. (tar spot)
- *Stereum purpureum* (Pers.:Fr.) Fr. (silver leaf)
- *Uncinula salicis* (DC. ex Mérat) Wint. (powdery mildew)
- See also Broadleaf trees, decay fungi

***Solidago* spp. (goldenrod):**
- *Coleosporium asterum* (Diet.) Syd. (pine needle rust)

***Sorbus* spp. (mountain ash):**
- ***americana* Marshall (American mountain ash)**

decora **(Sarg.) Schneid. (showy mountain ash)**
Erwinia amylovora (Burr.) Winsl. et al. (fire blight)
Phyllactinia guttata (Fr.) Lév. (powdery mildew)
Stereum purpureum (Pers.:Fr.) Fr. (silver leaf)

Stellaria **spp. (chickweed):**
Melampsorella caryophyllacearum Schroet. (witches' broom rust of fir)

Syringa **spp. (lilac; introduced):**
Microsphaera penicillata (Fr.) Farl. (powdery mildew)

Ulmus **spp. (elm):**
americana **L. (American elm)**
pumila **L. (Siberian elm; introduced)**
Ceratocystis ulmi (Buis.) C. Moreau (Dutch elm disease)
Dothiorella ulmi Verrall & May (wilt)
Hylurogopinus rufipes (Eichh.) (native elm bark beetle)
Scolytus multistriatus (Marsh.) (European elm bark beetle)
Verticillium albo-atrum Reinke & Berth. (wilt)
See also Broadleaf trees, decay fungi

Vaccinium **spp. (blueberry, cranberry, huckleberry, grouse-berry):**
scoparium **Leiberg (grouse-berry)**
Pucciniastrum goeppertianum (Kuehn) Kleb. (fir needle rust)

Viburnum lentago **L. (viburnum):**
Coleosporium viburni Arth. (needle rust of hard pines)

GLOSSARY

Acervulus (pl. acervuli): A mat of hyphae bearing a cushion of short conidiophores and conidia.

Actinorrhiza (pl. actinorrhizae): The symbiotic association of Actinomycetes with the roots of higher green plants in which the organism lives in close association with root cells, especially those at the root surface, and often produces root nodules.

Aeciospore: A binucleate spore produced in an aecium of a rust fungus.

Aecium (pl. aecia): A spore state of a rust fungus that produces aeciospores; often associated with spermogonia.

Alternate host: One or the other of the two different hosts of a host-alternating (heteroecious) rust.

Anamorph: The nonsexual, or imperfect, state of a fungus; compare holomorph and teleomorph.

Annual: Lasting only one year or one growing season.

Annulus: A ringlike veil on the stem of a mushroom.

Apothecium (pl. apothecia): A cup- or disc-shaped ascocarp.

Appressed: Pressed closely to or lying flat against something.

Ascocarp: The ascus-bearing organ of an ascomycete.

Ascoma (pl. ascomata): An ascus-containing structure; also called an ascocarp.

Ascomycete: a fungus belonging to the class Ascomycetes.

Ascospore: The sexually produced spore of an ascomycete.

Ascostroma (pl. ascostromata): A type of ascocarp, which is a mass of fungal tissue containing asci.

Ascus (pl. asci): A saclike cell of an ascomycete within which ascospores are produced.

Autoecious: Completing a life cycle on one kind of host; compare heteroecious.

Bacterium (bacteria): A unicellular microscopic organism that lacks chlorophyll and multiplies by fission.

Basal cups: Cuplike structures of dwarf mistletoe that remain on the branches of the host tree after the aerial shoots fall off.

Basidiocarp: The basidia-bearing organ of a basidiomycete.

Basidiospore: A spore produced on a basidium.

Basidium (pl. basidia): In a basidiomycete, a spore-bearing structure in which meiosis occurs.

Biclavate: Clublike on both ends, with a constricted center section.

Bifusiform: Both ends spindle shaped, with a constricted center section; dumbbell shaped.

Bifusoid: Both ends somewhat spindle shaped with a constricted center section.

Blight: Sudden and severe damage to leaves, flowers, and stems.

Burl: A hemispherical growth on a tree stem.

Cambium: A meristematic layer of cells lying between xylem and phloem.

Canker: A lesion on a stem, surrounded by living tissue.

Cerato-ulmin: A toxin produced by the pathogen of Dutch elm disease and thought to be responsible for wilting of infected trees.

Chlorosis: Yellowing of normally green tissue due to destruction of chlorophyll or failure of chlorophyll to develop

Clavate: Club shaped.

Cleistothecium (pl. cleistothecia): An enclosed ascocarp without an opening; typical of a powdery mildew; compare perithecium.

Concolorous: Of the same color.

Conidiophore: A simple or branched hypha bearing conidia-producing cells.

Conidium (pl. conidia): An asexual propagating spore.

Conk: Common term for a fruiting body of a wood-decay fungus.

Cuticle: A continuous noncellular layer covering the aerial parts of a higher plant.

Damping-off: Death of seeds or seedlings, usually by soil-borne fungi.

Decay: Disintegration of wood tissue.

Dieback: Death of extremities of the branches or leaves.

Dioecious: Having male and female organs on different individuals of the same species.

Eccentric: Off-center.

Effused-reflexed: Flat basidiocarp on the substratum, with turned-up edges.

Ellipsoid: A mass that is round in cross section and elliptical in side view.

Elliptical: Of elongated circular shape; the shape of an ellipse.

Endophytic: Situated within plant tissues.

Epidermis: The outer cell layer of higher plants.

Epiphyte: An organism living on the surface of another but not as a parasite.

Erumpent: Breaking through the host tissue.

Falcate: Curved like the blade of a scythe or sickle.

Filiform: Threadlike.

Fruiting body: Fungal structure of fungus containing or bearing spores.

Fungicide: A chemical agent that kills or inhibits fungi.

Fungus (pl. fungi): An organism without chlorophyll, usually having a mycelium and sexual and/or asexual spores.

Fusiform: Spindle shaped, narrowing toward the ends.

Fusoid: Somewhat fusiform.

Gall: Outgrowth or swelling that is often more or less spherical.

Germ pore: An area, or hollow, in a spore wall (especially in rust fungi) through which a germ tube may grow.

Globose: Spherical or almost so.

Heartwood: The central part of a tree that does not conduct water.

Herbicide: A chemical that kills weeds or weed seeds.

Heteroecious: Completing a life cycle on two kinds of hosts; compare autoecious.

Holomorph: Having both the sexual and asexual spore states of a fungus; compare anamorph and teleomorph.

Host: Any plant attacked by a parasite or pathogen.

Hyaline: Transparent, colorless.

Hygroscopic: Sensitive to moisture.

Hymenium (pl. hymenia): The spore-producing layer of a sporophore of a basidiomycete.

Hyperparasite: A parasite living on a parasite of another organism.

Hyperplasia: The production of an abnormally large number of cells; compare hypertrophy.

Hypertrophy: An abnormal increase in the size of cells; compare hyperplasia.

Hypha (pl. hyphae): The threadlike filament of a fungus.

Hyphal peg: A peglike bundle of hyphae arising from a cushion of fungus, typical of the conidial state of the Hypoxylon canker pathogen.

Hypodermis: A layer of cells below the epidermis of coniferous needles.

Hysterothecium (pl. hysterothecia): An elongated ascocarp of a needle cast fungus, usually with a central slit.

Ice-nucleating agent (INA): An organism or a chemical compound capable of creating ice crystals above the freezing temperature.

Imperfect state: The asexual state of a fungus; also called an anamorph.

Intrahypodermal: Living within the hypodermis.

Locule: a cavity in a fungal stroma.

Mold: The common name for a visible fungus growing on the surface.

Mushroom: A large fruiting body of a fungus.

Mycangium (pl. mycangia): A specialized sac located in the mouth area of a beetle and containing various species of fungi, especially yeasts.

Mycelium (pl. mycelia): A mass of fungal hyphae.

Mycoparasite: A fungus parasitic on another fungus.

Mycophagous: Fungus eating.

Mycoplasma: A genus of the family Mycoplasmataceae; minute nonmotile microorganisms that are intermediate in some respects between viruses and bacteria.

Mycorrhiza (pl. mycorrhizae): The symbiotic association of certain fungi with the roots of higher green plants in which the fungus lives in close association with the root cells, especially those at the root surface.

Necrosis: Death of plant tissue.

Needle cast: Loss or casting of needles of coniferous trees.

Ovoid: Shaped like an egg.

Parasite: An organism living in or on another living organism and obtaining its nutrients from the host; compare saprophyte.

Pathogen: An organism capable of causing disease.

Perennial: Lasting more than one year.

Perfect state: The sexual state of a fungus; also called a teleomorph.

Periderm: The outermost corky layer of the bark of a tree.

Peridermioid teliospore: Teliospores having the morphology of aeciospores of *Peridermium*; occurs in the western gall rust pathogen, *Endocronartium harknessii*.

Peridermium (pl. peridermia): A type of aecium of a rust fungus with a *Peridermium*-type sorus.

Perithecium (pl. perithecia): A flask-shaped ascocarp of an ascomycete, with a conspicuous top opening; compare cleistothecium.

Phloem: Vascular tissue that conducts synthesized foods through plants; occurs outside of the cambium layer in trees; compare xylem.

Powdery mildew: A fungus belonging to the order Erysiphales of the class Ascomycetes.

Pseudosclerotium (pl. pseudosclerotia): A compact mass of fungal mycelium intermixed with soil or plant tissue; a survival mechanism of a fungus.

Pseudothecium (pl. pseudothecia): An ascostromatic ascocarp having asci in unwalled locules.

Pycnidium (pl. pycnidia): A flask-shaped conidia-producing structure usually with an ostiole (mouth).

Resinosis: Excessive outflow of resin from coniferous plants; usually resulting from injury or disease.

Resupinate: A flat basidiocarp with a spore-producing outer layer.

Rhizomorph: A rootlike bundle of hyphae.

Rot: Disintegration and decomposition of plant tissue accompanied by discoloration.

Rust: A fungus belonging to the order Uredinales of the class Basidiomycetes.

Saprophyte: An organism using dead organic material as food; compare parasite.

Sapwood: The water-conducting outer portion of a tree stem below the cambium.

Sclerotium (pl. sclerotia): A firm, often dark-colored and rounded sterile mass of fungal hyphae; a survival mechanism of a fungus.

Semiglobose: Semispherical.

Septum (pl. septa): A wall, cross-wall, or partition.

Shelving: Flat fruiting bodies of fungi that grow one on top of the other, similar to shelves.

Sign: A characteristic structure of the causal agent of a disease; compare symptom.

Sordid: Of a dull or muddy color.

Sorus (pl. sori): A structure that produces spore masses; especially in rust fungi.

Spermatium (pl. spermatia): A noninfecting sexual gamete.

Spermogonium (pl. spermogonia): A spermatium-producing organ.

Spore: A general term for a reproductive propagule of fungi, bacteria, and other lower plants.

Sporodochium (pl. sporodochia): A cushionlike mass of conidiophores.

Sporophore: A spore-producing or spore-supporting structure.

State: A phase of the fungus life cycle.

Stipe: A stem or stalk of a fruiting body of a fungus.

Stroma (pl. stromata): A mass of fungal tissue packed tightly.

Subcuticular: Produced under the cuticle and above the epidermis of a leaf.

Subepidermal: Produced under the epidermis of a leaf.

Subhypodermal: Produced under the hypodermis of coniferous needles.

Symptom: A visible reaction by a host plant to a disease; compare sign.

Synnema (pl. synnemata): A cemented fascicle of erect conidiophores, with a head of conidia-bearing branches; also called a coremium.

Systemic: Distributed throughout an organism.

Teleomorph: Having the sexual (perfect) state of a fungus; compare anamorph and holomorph.

Teliospore: A spore state of a rust fungus that germinates to produce a basidium.

Telium (pl. telia): A sorus that bears teliospores.

Urediniospore: A repeating vegetative spore of a rust fungus.

Uredinium (pl. uredinia): A sorus of a rust fungus that produces urediniospores.

Vacuole: A cavity in the cytoplasm, usually filled with fluid.

Vector: An organism (usually an insect) that can transmit a disease.

Verrucose: Having small, rounded processes or warts.

Viscin: A clear, sticky, tasteless substance from the mucilaginous sap of the mistletoe.

Wilt: Loss of freshness or drooping of plants; a disease causing wilting symptom.

Witches' broom: A proliferation of branches caused by a disease or other causes.

Xylem: The water-conducting tissue of higher plants; in trees it is produced inward from the cambium; compare phloem.

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